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Net-zero Climate Resilient City Action Plan 2070

Tirunelveli 2024

south pole

ICLEI Local Governments for Sustainability SOUTH ASIA

econcept
Research / Consulting / Evaluation

NIUA National Institute of Urban Affairs

November 2024

Tirunelveli Net-zero Climate Resilient City Action Plan 2070 was led by Tirunelveli City Municipal Corporation and developed jointly with the implementing partners of the "Capacity Building for Low Carbon and Climate Resilient City Development - Phase II (CapaCITIES II)" Project, supported by the Swiss Agency for Development and Cooperation (SDC). Tirunelveli is one of eight partner cities of the CapaCITIES II project, being implemented by ICLEI-Local Governments for Sustainability, South Asia, the South Pole Group, and econcept AG, with the National Institute of Urban Affairs (NIUA) as a knowledge partner.

The Tirunelveli City Municipal Corporation acknowledges the SDC and all the project partners for their support provided under the CapaCITIES II project towards our efforts on climate action and for the development of this strategic document. Tirunelveli City Municipal Corporation would like to thank all the advisors, stakeholders and external agencies who participated in the stakeholder consultations for preparation of this plan. The support and contributions from government departments, institutions, private entities and all stakeholders are well-acknowledged.

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Net-zero Climate Resilient City Action Plan 2070

Tirunelveli

August 2024

Foreword by Mayor, Tirunelveli City Municipal Corporation

திருநெல்வேலி நகரதிர்க்கென உருவாக்கப்பட்ட கால நிலை மாற்றத்தை எதிர்நோக்கும் மாநகர செயல் திட்டத்தை உங்கள் முன்னிலையில் பரிமாறுவதில் எனக்கு பெருமை மற்றும் பொறுப்புணர்வு ஏற்படுகிறது. இந்த வரலாற்று சிறப்புமிக்க மற்றும் உயிரோட்டமிக்க நகரத்தின் மேயராக இருப்பது எனக்கு பெருமையும் திருநெல்வேலியின் கால நிலை மாற்றத்தை எதிர்கொள்ளக்கூடிய எதிர்காலத்திற்கான வழியை கட்டமைப்பது நம் ஒவ்வொருவரின் கடமையாகவும் இருக்கிறது.

ஆழமான பண்பாட்டு அடிப்படைகளையும் வளமான இயற்கை மரபுகளையும் கொண்டுள்ள நமது திருநெல்வேலி மாநகரம் நீண்ட காலத்திற்கு கால நிலை மாற்றங்களை எதிர்நோக்கும் திறன் கொண்ட நகரமாக திகழ்ந்து வருகிறது. எனினும் உலகளாவிய கால நிலை மாற்ற சவால்கள், நமது சுற்றுச்சூழல் வளங்கள் மற்றும் அடிப்படை வசதிகளை எவ்வாறு மேலாண்மை செய்வது என்பதில் புதுமையான சிந்தனைகள் மற்றும் ஆலோசனைகளை செய்து அவற்றை செயல்படுத்த வேண்டியது காலத்தின் கட்டாயமாக உள்ளது.

வெப்பநிலை அதிகரிப்பு, காலநிலை மாறுபாடுகள் மற்றும் இயற்கை பேரழிவுகள் அதிகரிக்கும் போது உடனடியாக கூட்டு நடவடிக்கை எடுப்பது அவசியமாகின்றது. இந்த செயல் திட்டமானது எதிர் வருகின்ற சவால்களை எதிர்கொண்டு திருநெல்வேலி மாநகர மக்களின் சுமூகமான வாழ்க்கை முறையைத் தீர்மானிப்பது மட்டுமல்லாது நிலைத்த வளர்ச்சியின் முன்னோடியாக திகழும் வகையில் வழிகாட்டுகிறது.

சுற்றுச்சூழல் பாதுகாப்புடன் பொருளாதார வளர்ச்சியை ஒருங்கிணைக்கும் இந்த செயல் திட்டம் நமது மாநகரத்தின் பசுமை இல்ல வாயுக்களின் உமிழ்வுகளை (Greenhouse Gas Emissions) குறைப்பதற்கான தெளிவான பாதைகளை வகுக்கின்றது. நமது நகர அடிப்படை வசதிகளை கால நிலை மாறுபாடுகளை எதிர்கொள்ளக்கூடியவையாக மாற்றுவதும் பசுமை எரிசக்தி பயன்பாட்டை மேம்படுத்துவதும் கழிவுகளை சிக்கனமாக நிர்வகிப்பதிலும் நாம் அனைவரும் ஒன்றிணைந்து செயல்பட வேண்டியது இன்றியமையாதது ஆகும்.

இதை அரசாங்கத்தின் செயல்முறையால் மட்டும் அடைய முடியாது. திருநெல்வேலியின் ஒவ்வொரு குடிமகனும் ஏனைய பொதுநலன் சார்ந்த அமைப்புகளும் வணிக நிறுவனங்களும் இந்த செயல்பாட்டில் பங்குபெற வேண்டும். சுற்றுச்சூழலுக்கு நாம் ஏற்படுத்தும் தாக்கத்திற்கு ஒவ்வொருவரும் பொறுப்பேற்று நமது சமூக நலனுக்காகக் கட்டுப்பாடோடு செயல்படுவதற்கான நிலைத்த வளர்ச்சியை நோக்கிய கலாச்சாரத்தை நாம் உருவாக்க வேண்டும்.

இந்த காலநிலை மாற்றத்தை எதிர்கொள்ளக் கூடிய செயல்முறையை தொடங்கியுள்ள நிலையில் இந்த திட்டத்தை உருவாக்கியதற்காக பங்களித்துள்ள அனைத்து நிபுணர்கள் அதிகாரிகள் மற்றும் சமூக அங்கத்தினர்களுக்கும் எனது மனமார்ந்த நன்றிகளைத் தெரிவித்துக் கொள்கிறேன். திருநெல்வேலியின் குடிமக்கள் அனைவரும் இந்த செயல்திட்டதினை ஏற்றுக்கொண்டு நமது நகரத்தை கால நிலை மாற்றத்தை எதிர்கொள்ளக்கூடிய முன்னோடியான நகரமாக மாற்ற உதவிடுமாறு வேண்டுகிறேன்.

வரலாற்றிலும் மரபிலும் மட்டும் அல்லாது சுற்றுச்சூழல் பாதுகாப்பிலும் கால நிலை மாற்றத்தை எதிர்கொள்ளும் திறனிலும் முன்னோடியாக திகழும் திருநெல்வேலியை நாம் உருவாக்குவோமாக. இன்று எடுக்கப்படும் நமது கூட்டு நடவடிக்கை அனைத்தையும் நாளைய திருநெல்வேலியின் வடிவமைப்பை உறுதிப்படுத்தும்—ஒரு சுத்தமான பசுமையான மற்றும் கால நிலை மாற்றங்களை எதிர்கொள்ளும் திறனை கொண்ட மாநகரமாக மாறும் என்பதில் எனக்கு திடமான நம்பிக்கை உள்ளது.

மாண்புமிகு மேயர்
திருநெல்வேலி மாநகராட்சி

Foreword by Commissioner, Tirunelveli City Municipal Corporation

It gives me immense pleasure to present the Tirunelveli Net-zero Climate Resilient City Action Plan, a significant milestone in our journey towards sustainable urban development. As one of the oldest non-metropolitan cities in India, Tirunelveli holds a rich cultural heritage, and it is our collective responsibility to ensure that this heritage continues to flourish in a future defined by sustainability, climate resilience, and environmental responsibility.

Extreme weather events, rising temperatures, and unpredictable rainfall patterns are affecting not only the environment but also public health, infrastructure, and the economy. As a fast-developing urban area, Tirunelveli city is no exception and is vulnerable to the consequences of climate change. Recognizing the urgency, we have developed this comprehensive climate resilient city action plan, which aims to transform Tirunelveli into a net-zero, climate-resilient city by reducing emissions, enhancing urban resilience, and promoting sustainable practices.

This plan outlines a roadmap for our city to adopt low-carbon development strategies across various sectors, including energy, transportation, waste management, and urban planning. At its core, it is about building a city that not only meets the needs of today but also prepares for the uncertainties of tomorrow. Through integrated solutions and collaborative efforts, Tirunelveli will address key challenges such as energy efficiency, renewable energy adoption, electric mobility, sustainable urban development and biodiversity conservation.

The transition to a net-zero and climate-resilient city is no small task. It requires the cooperation of every citizen, institution, and business in Tirunelveli. Our success in achieving these ambitious goals will be determined by our collective commitment to innovation, collaboration, and sustainable growth.

As the Commissioner of Tirunelveli City Municipal Corporation, I am proud to lead this initiative. I would like to sincerely thank all the stakeholders, experts, and citizens who have contributed to the development of this action plan. Together, we can ensure that Tirunelveli continues to thrive as a model of sustainability, offering a high quality of life to its residents and safeguarding its environment for future generations.

I invite everyone to join hands in making Tirunelveli a net-zero and climate-resilient city, where progress and preservation go hand in hand.

Sincerely,

Dr. N.O. Sukhaputra IAS,
Commissioner,
Tirunelveli City Municipal Corporation

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Embassy of Switzerland
Swiss Cooperation Office in India

Foreword

It is with great enthusiasm and admiration that I congratulate the Tirunelveli City Municipal Corporation for its pioneering efforts in advancing climate resilience through the preparation of the Net-Zero Climate Resilient City Action Plan 2070 (Net-zero CRCAP) for Tirunelveli. This landmark initiative has been supported by the Capacity Building for Low-Carbon and Climate Resilient Cities in India (CapaCITIES) Project, funded by the Swiss Agency for Development and Cooperation (SDC), marking a significant stride towards addressing the complex challenges posed by climate change and urbanization. Urban centres like Tirunelveli are at the forefront of climate action. As dynamic hubs of economic activity and population growth, cities contribute significantly to greenhouse gas emissions and face heightened vulnerability to the impacts of climate change. The need for cities to lead in achieving climate resilience while balancing effective municipal service delivery and socio-economic development is more pressing than ever. The Net-zero CRCAP 2070 is a testament to Tirunelveli's commitment to this critical endeavour. The CapaCITIES Project, which began in 2016 and expanded in 2019 to include eight Indian cities, has played a pivotal role in integrating climate action into urban planning and decision-making. By focusing on areas such as renewable energy, water supply, and waste management, CapaCITIES has empowered partner cities, including Tirunelveli, to enhance their climate resilience and reduce greenhouse gas emissions.

The commitment made by India at COP26 in Glasgow in 2021 to achieve net-zero emissions by 2070 reflects a broader dedication to climate resilience and sustainable development. Tirunelveli's Net-zero CRCAP 2070 is aligned with this ambitious national goal and contributes to the objectives of Tamil Nadu's State Action Plan on Climate Change. This plan not only supports India's Nationally Determined Contributions (NDCs) but also demonstrates Tirunelveli's proactive role in advancing climate resilience and contributing to global climate goals based on Tirunelveli's commitment and experience.

Developed through comprehensive scientific assessments and robust multi-level stakeholder collaboration, the Net-zero CRCAP 2070 sets a benchmark for other cities. It highlights the essential role of urban canters in achieving net-zero emissions while ensuring equitable development and maintaining effective municipal services. As we look forward to the implementation of the climate actions outlined in this plan, it is crucial that the Net-zero CRCAP be periodically updated to incorporate emerging climate solutions, government schemes, and evolving missions, ensuring its long-term relevance and impact. This achievement represents a significant milestone in Tirunelveli's journey toward a sustainable and resilient future. It is an inspiring example of how cities can lead in addressing climate change and setting ambitious targets for a greener world. I commend the Tirunelveli City Municipal Corporation and the CapaCITIES Project for their vision and dedication, and I eagerly anticipate the positive outcomes that will arise from this forward-thinking plan.

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Foreword by Executive Director, ICLEI South Asia

In an era where cities across the globe are grappling with the realities of climate change, it is imperative that we take bold, proactive measures to safeguard our communities, economies, and ecosystems. The city of Tirunelveli, though a non-metropolitan city, is standing at the forefront of this movement, embracing the challenge to transition towards a net-zero carbon future while enhancing resilience to climate impacts.

ICLEI South Asia, as a key partner to Tirunelveli in this transformative journey, has been providing technical support and policy guidance to the city under the CapaCITIES Phase II project, funded by the Swiss Agency for Development and Cooperation. Our goal has been to empower the city with the tools and knowledge needed to address its unique challenges while aligning with global climate action frameworks like the Paris Agreement and the Sustainable Development Goals (SDGs).

This Net-zero Climate Resilient City Action Plan is a culmination of extensive research, consultations, and collaborative efforts by various stakeholders. From local government officials and urban planners to community representatives and technical experts, the creation of this plan reflects the collective vision of Tirunelveli's residents and leaders to ensure a sustainable and thriving future. This plan not only outlines a pathway to achieving net-zero emissions but also integrates strategies for building resilience against climate hazards such as floods, heatwaves, and droughts.

I would like to extend my heartfelt gratitude to the Tirunelveli City Municipal Corporation and local stakeholders for their dedication to the climate cause. I encourage and will continue to support Tirunelveli in the implementation of the action plan. It is my sincere hope that this document will serve as a beacon for other non-metropolitan cities across the region, inspiring them to embark on their own journeys toward sustainability and climate resilience.

Together, we can create cities that are climate-friendly, while also improving liveability, inclusivity and prosperity. The journey ahead may be challenging, but with commitment, innovation, and collaboration, we can achieve the future we envision.

Emani B.V Kumar
Executive Director, ICLEI South Asia
Deputy Secretary General, ICLEI Global

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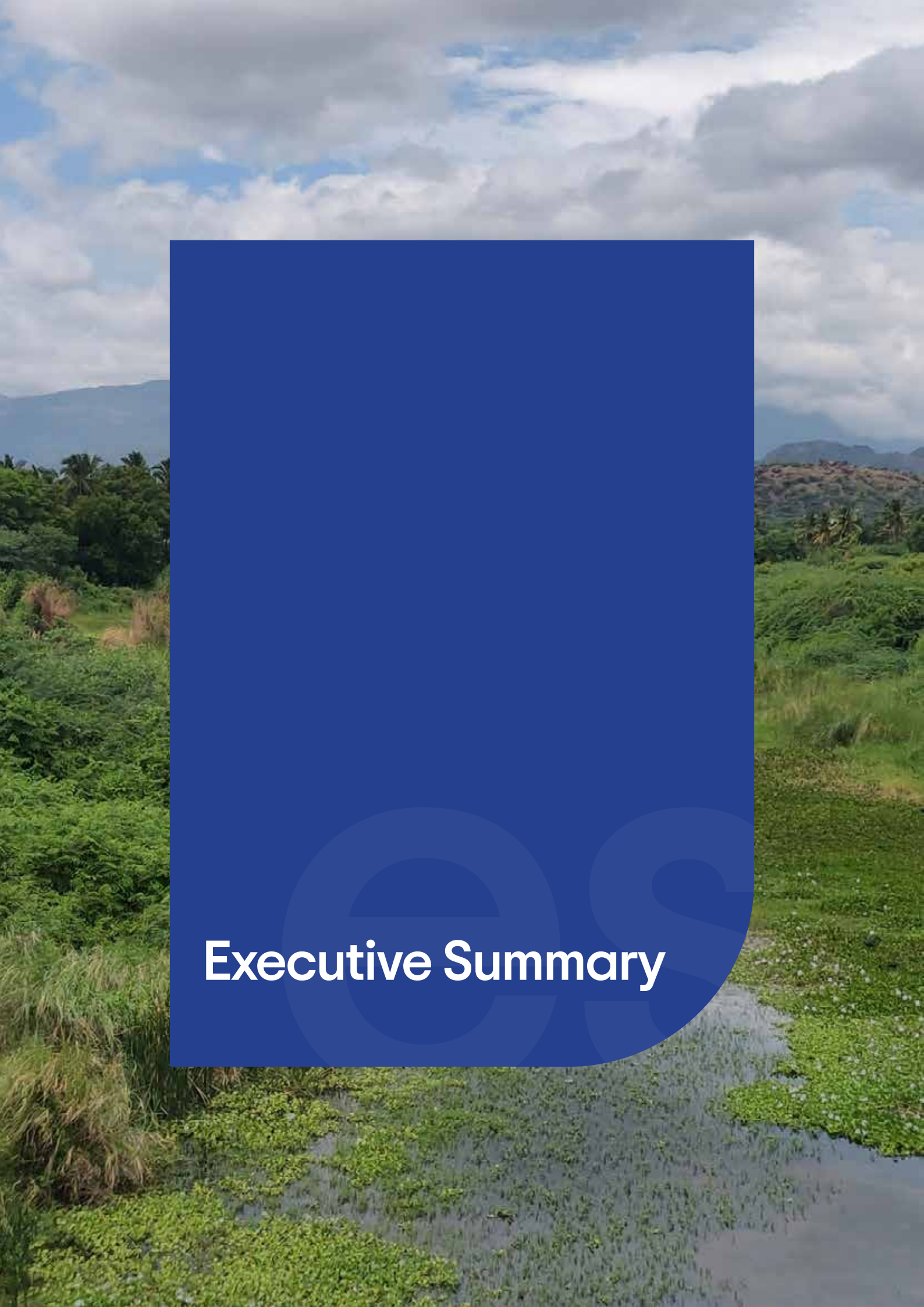
Abbreviations

AFOLU - Agriculture, Forestry, and Other Land Use
AMRUT – Atal Mission and Rejuvenation and Urban Transition
AQI – Air Quality Index
BAU – Business As Usual
BOD – Biological Oxygen Demand
BRTS - Bus Rapid Transit System
CAAQMS - Continuous Ambient Air Quality Monitoring system
C&D - Construction & Demolition
CER – Corporate Environment Responsibility
CH4 – Methane
CMP – Comprehensive Mobility Plan
CNG – Compressed Natural Gas
CO – Carbon Monoxide
CO2 - Carbon Dioxide
COD – Chemical Oxygen Demand
CPEEHO – Central Public Health and Environmental Engineering Organisation
CRC – ClimateResilientCities
CRCAP - Climate Resilient City Action Plan
CRVA - Climate Risks and Vulnerability Assessment
CSCAF - Climate Smart Cities Assessment Framework
CSCAF – Climate Smart Cities Assessment Framework
CSOs – Civil Society Organizations
CSR – Corporate Social Responsibility
DBT - Direct Benefits Transfer
DEWATS – Decentralised Wastewater Treatment Systems
DMA – Directorate of Municipal Administration
DoECCF - Department of Environment, Climate Change & Forest
DPR – Detailed Project Report
DTCP – Department of Town and Country Planning
ELCOT - Electronics Corporation of Tamil Nadu Limited
EE – Energy Efficiency

EEFP - Energy Efficiency Financing Platform
EFI – Environmentalists Foundation of India
EVs - Electric Vehicles
ESCO – Energy Services Company
FAME - Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
FC – Finance Commission
FOD - First Order Decay
GDP – Gross Domestic Product
GHG – Green House Gases
GoI - Government of India
GoTN - Government of Tamil Nadu
GJ – Giga Joules
GCoM - Global Covenant of Mayors
GIS – Geo Information System
GPC - Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
GTNM - Green Tamil Nadu Mission
GWP - Global Warming Potential
HEAT+ - Harmonized Emission Analysis Tool Plus
HSCs - Health Sub-Centres
HT – High Tension
ICCC – Integrated Command & Control Centre
ICE - Internal Combustion Engine
ICLEI - International Council for Local Environmental Initiatives
IMD – Indian Meteorological Department
INR – Indian Rupee
INS – Indian Naval Station
IEC – Information, Education, and Communication
IOCL – Indian Oil Corporation Limited
IPCC - Intergovernmental Panel on Climate Change
IPPU - Industrial Processes and Product Use
IPT- Intermediate Public Transport
ISRO – Indian Space Research Organization

ICLEI



Executive Summary

Climate change, primarily driven by human activities resulting in unprecedented greenhouse gas emissions, poses a significant threat to modern societies and ecosystems, with scientific research identifying it as an 'existential threat' to human societies. The global surface temperatures have increased by 1.1°C above pre-industrial levels, and without substantial action the global temperatures could rise by 4.4°C by 2100, leading to significant rise in sea levels, and more frequent extreme weather events that can have severe impacts on coastal and island communities.

India, with its average temperature increase of 0.7°C, faces severe impacts such as intensified heatwaves, altered monsoon patterns affecting agriculture, and rising sea levels threatening coastal communities in the peninsular India. India, affirming its commitment to addressing the climate crisis, pledged to achieve net-zero emissions by 2070 at the COP26 in Glasgow in 2021. The country updated its Nationally Determined Contribution (NDC) under the Paris Agreement, aiming to cut its GDP's emissions intensity by 45% by 2030 from 2005 levels and to fulfill 50% of its electricity needs through non-fossil fuel sources.

Addressing the climate challenges requires comprehensive strategies at all governance levels to protect vulnerable populations and ensure sustainable development. Global frameworks such as the 2016 New Urban Agenda by UN-Habitat emphasize the crucial role of local and regional governments in fostering climate resilience and sustainability. The 2018 IPCC Special Report underscores the need for local climate action to limit global warming to 1.5°C, especially in rapidly growing cities in South Asia and Africa.

Tamil Nadu, as a coastal state vulnerable to climate change and its impacts, understands the importance of climate policies and action planning in its fight against climate change. Tamil Nadu has launched the first dedicated state level 'Tamil Nadu Climate Change Mission' along with complementing programs, showcasing its vision and leadership in local initiatives. It is also a leading state in proliferation of renewable energy sources, contributing significantly to India's climate goals and targets.

Tirunelveli city in Tamil Nadu, situated on the banks of Thamirabarani River, has a rich cultural heritage and has been the epicenter of urbanization and development in the southern region of Tamil Nadu beyond Madurai. Notably, the city is emerging as a key hub for industrial and economic development in the region and its population which was estimated to be 0.55 million in 2021, is projected to increase to 0.68 million by 2031, 0.85 million by 2051, and 0.97 million by 2071.

Tirunelveli's rapid urbanization poses formidable challenges to the city of Tirunelveli going forward, as the city is already grappling with significant burden on its urban service infrastructure and limited resources, which will be further exacerbated by climate hazards such as riverine flooding, extreme rainfall, drought and urban heat events. Some of the key challenges faced by urban services in Tirunelveli are:

Water Supply: Tirunelveli faces challenges in its water supply as it is dependent solely on the Thamirabarani River leading to a lack of continuous and adequate water supply. This has led to unregulated groundwater extraction depleting the groundwater table, especially in summer months when groundwater levels are already found to be low, increasing water security risks for the city.

Wastewater Management: Inadequate underground sewerage network, low wastewater treatment capacity, lack of reuse of treated wastewater and poor wastewater management practices lead to several challenges in wastewater management. Untreated wastewater is often led directly into waterbodies in the city, and heavy rainfall during monsoon season impacts the sewerage network, often leading to contamination and health related issues.

Stormwater Management: Inadequate and poorly maintained stormwater drainage network, and poor urban planning practices have led to increased risks of urban flooding in the city. Openly dumped municipal solid waste in the drains often chokes the flow of stormwater and contaminates it. Mixing of sewerage from open manholes with stormwater have also cause health issues due to contamination.

Solid Waste Management: Lack of source segregation of waste, poor functioning of the existing network of micro-compost centers, lack of dedicated dry waste recycling centers has led to most of the waste reaching the Ramayanpatti landfill site as mixed waste. Open dumping of garbage is prevalent due to inefficiencies in solid waste management, and lack of scientific management of the dumping site and legacy waste leads to frequent landfill fires during summer months.

Transportation: Tirunelveli's unique development surrounding the 4 urban centers that formed the city has led to high density developments connected through arterial roads and major traffic junctions which are often narrow and face congestion during peak hours and holidays or festivals. Limited parking facilities, poorly planned transport nodes and junctions, and inefficient public transport due to poor

coverage and lack of integration with intermediate transport modes are some of the key challenges to Tirunelveli's transport system.

Tirunelveli City Municipal Corporation (TCMC) has proactively embarked on developing sustainable infrastructure to meet the future urban service demands of the city under various state and national level programs and missions such as the Smart City Mission, Swachh Bharath Mission, Atal Mission for Rejuvenation and Urban Transformation, Tamil Nadu Sustainable Urban Development Project and Tamil Nadu Climate Resilient Urban Development.

TCMC envisions promoting climate-resilient urban planning and infrastructure development and emphasizing sustainable practices across all sectors. Tirunelveli is actively implementing the CapaCITIES Phase II project, funded by the Swiss Agency for Development and Cooperation (SDC), to bolster its capacity to plan and implement local climate resilience actions. Tirunelveli has developed this Net-zero Climate Resilient City Action Plan (CRCAP) as a guidance for its vision to achieve net-zero emissions by 2070, with technical support from the project.

The Tirunelveli Net-zero CRCAP positions Tirunelveli as a climate-conscious city keen to plan and implement local climate actions proactively in alignment with Tamil Nadu State Action Plan for Climate Change, the Nationally Determined Contributions (NDC) goals and targets, and global frameworks such as the Paris Agreement and SDGs. Tirunelveli envisions to lead as example for non-metropolitan cities in India by transitioning towards a net-zero emissions future and building climate resilience of the city in the face of increasing climate risks from flooding, cloud bursts, drought and heat waves.

The following sections provide key highlights of the assessments undertaken for development of Tirunelveli's Net-zero CRCAP and the identified strategies and targets across the urban service sectors

Climate Risk & Vulnerability Assessment of Tirunelveli

Tirunelveli District Disaster Management Plan identified flooding, cloudbursts, and heat waves as the key climate hazards faced by the city. The climate risk and vulnerability assessment for Tirunelveli includes analysis of historical weather data for identifying climate trends and future projections, assessment of grievance data for identifying climate risks and vulnerability of each ward to urban services provided by local government departments, along with spatial analyses and stakeholder discussions.

Climate trends and projections of Tirunelveli:

Analysis of the local rainfall data from 1969 to 2022, using data from Indian Meteorological Department (IMD), shows a slight decrease in decadal average annual rainfall received by the city. The analysis of temperature data recorded between 1951 and 2019 by Climate Studio, Anna University shows substantial increase in average and extreme temperatures. The climate scenario and projections reveal an increasing trend for rainfall and temperature.

Air temperature trend analysis: Analysis of annual average maximum and minimum air temperatures from 1951 to 2019 indicates that the annual average maximum temperature is 32.0°C and the annual average minimum temperature is 23.2°C. The maximum air temperature has increased by 1.34°C, while the minimum air temperature has increased by 0.6°C during the period of analysis.

Rainfall trend analysis: The annual rainfall for Tirunelveli increased by an average of 1.2 mm per year between 1969 to 2022. The decadal average of annual rainfall decreases slightly by an average of 12 mm per decade from 1971 to 2020, however, the average number of rainy days have increased consistently, and by 15% alone in the last decade, indicating more frequent low-intensity rainfall. In the last decade, Tirunelveli has experienced 33 heavy rainfall events and the annual rainfall recorded increased by an average of 272 mm in 2014, 2015, 2017, 2019, and 2021. The last decade also witnessed extreme rainfall events of more than 100 mm rainfall received within 24 hours in 2015, 2019 and 2021.

Climate projections and scenario statements: Temperature projections reveal that under different Shared Socio-economic Pathways (SSP), the annual average maximum temperature increases by 0.7°C and 1.8°C and the annual average minimum temperature increases by 1.1°C and 2.3°C, towards the end of century. The analysis of the precipitation patterns in this century shows that the annual average rainfall increases by 15.4% mid-century and by 19.3% towards end of century based on SSP2 4.5 scenario. Thus, the climate projections undertaken by Climate Studio, Anna University, based on historical trends from 1985 to 2014, show an increase in average temperatures and rainfall in the long term for Tirunelveli under different scenarios.

Vulnerability to urban heat risks:

- Tirunelveli will be exposed to increasing heat risks due to projected rise in temperatures.
- Land Surface Temperature (LST) analysis shows that areas in the city with LST exceeding the median value of 30°C are exposed to urban heat risks.
- Densely developed residential locations and commercial centers with limited green cover are identified as hotspots to urban heat risks in the city. The eastern half of city faces substantially higher urban heat risks compared to the other half.
- 55.7 sq km of city area is considered as a hotspot for urban heat risks, and around 61.33% of the city's population living in the hotspot areas are vulnerable to urban heat risks.
- Vulnerable groups of population such as the elderly, children, differently abled and people with pre-existing health conditions such as diabetes, cardiovascular diseases are often prone to non-exertional heat stress leading to heat exhaustion or heat stroke.
- Vulnerable population groups such as the low-income group comprising of hard-working laborers or the slum-dwelling people are commonly exposed to exertional heat stress due to poor living and workplace conditions, and lack of affordable cooling options.

Vulnerability to urban flooding risks:

- Areas within 250 m of 119 flood vulnerable locations, identified and mapped based on field assessments and spatial analysis, are considered as high-risk areas prone to urban flooding.
- People living in high-risk locations across 31 wards face substantial risk of flooding during riverine floods in Thamirabarani River and heavy rainfall events in the city.
- 16.93 sq km of city area is prone to flooding and around 39.65% of the city population is vulnerable to urban flooding risks.
- Vulnerable groups of population such as the elderly, women, children and the disabled are exposed to the impacts of urban flooding.

Climate vulnerability of urban service systems:

- **Water supply:** Urban heat and flooding risks threaten the water supply and distribution infrastructure, impacting 20 wards in the city.
- **Wastewater management system:** Urban flood risks impact the existing wastewater management systems across 13 wards in the city.
- **Solid waste management:** 20 wards and 10 locations with SWM infrastructure face challenges in solid waste management due to impacts of urban flooding.
- **Transport system:** Public bus stations and major traffic junctions are impacted by urban heat risks, especially in the eastern parts of the city. 7 wards are impacted due to urban flooding and poor transport infrastructure.
- **Health:** 7 wards in the city have a greater number of public and private healthcare centers vulnerable to impacts of urban flooding.

GHG Emissions of Tirunelveli City

The greenhouse gas (GHG) emissions inventory for Tiruchirappalli is prepared for the period from 2017-18 to 2021-22 based on the Global Protocol for Community-Scale GHG Emissions (GPC) standards. The inventory assesses the GHG emissions at the city-level and the local government's contribution to the emissions due to its municipal operations

Total Energy Use	6.00 million GJ
Total GHG Emissions	0.73 million tCO2e
Per Capita Energy Use	10.83 GJ
Per Capita GHG Emissions	1.32 tCO2e

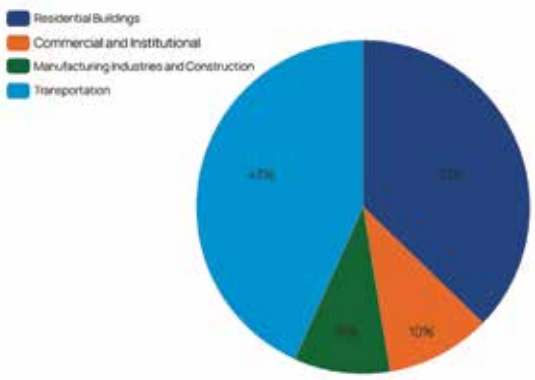


Figure E.1: Sector-wise share of energy consumption, 2021-22

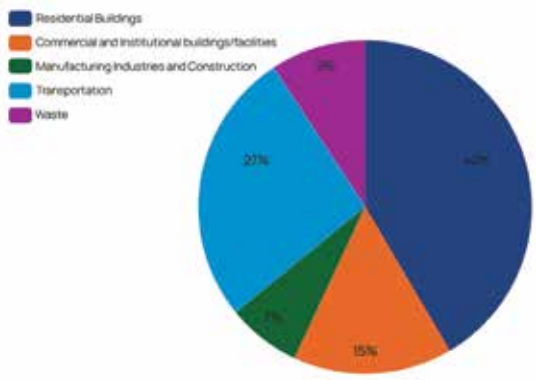


Figure E. 2: Sector-wise share of GHG emissions, 2021-22

Highlights in energy consumption and GHG emissions trends

Energy Consumption

Energy intensive sectors: Transport (43%), Residential Buildings (37%), Commercial and Institutional Buildings/Facilities (10%)

Energy consumption growth (2017-18 to 2021-22): 8.5% increase at 2.1% annually

GHG Emissions

Sectors with significant GHG emissions: Residential Buildings (42%), Transport (27%), and Commercial and Institutional Buildings/ Facilities (15%)

GHG emissions growth (2017-18 to 2021-22): 7.9% increase at 1.96% annually

Energy Consumption and GHG Emissions from Tirunelveli Municipal Operations, 2021-22:

Energy consumption and GHG emissions by TCMC for urban service operations have been assessed to identify the key emission contributors and identify targeted actions for various municipal infrastructure and urban services to reduce the carbon footprint of TCMC.

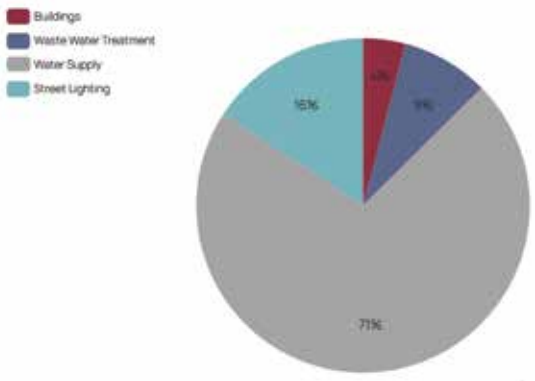


Figure E. 3: Electricity consumption from municipal operations (2021-22)

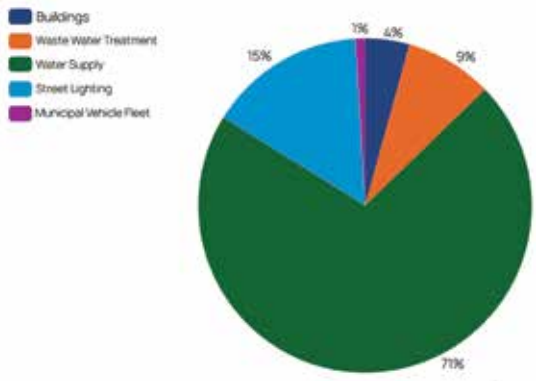


Figure E. 4: GHG emissions from municipal operations (2021-22)

Key findings:

Predominant electricity consumers: Water Supply (71%), Street Lighting (16%), and Wastewater Treatment (9%)

Trend of electricity consumption (2017-18 to 2021-22): 10.1% increase at 2.53% annually

Main contributors to GHG emissions: Water Supply (71%), Street Lighting (15%), and Wastewater Treatment (9%)

Trend of GHG emissions (2017-18 to 2021-22): 3.9% increase at 0.97% annually

Scenario Planning for Future GHG Emissions until 2070

The Tirunelveli Net-Zero CRCAP aims to mitigate GHG emissions in the city and bolster its urban climate resilience, with the goal of achieving net-zero emissions by 2070, and thus showcasing the transformative potential of sustainable practices and leading the way towards a brighter, more climate-conscious future. Scenario planning is integral to climate action planning for mitigation of GHG emissions in the city, as it addresses the uncertainties of future socio-economic and technological developments by identifying multiple potential scenarios for emissions reduction: Business-as-Usual (BAU), Progressive Action, and Net-zero Pathway scenarios.

The BAU scenario projects emissions without additional measures, showing that emissions could triple by 2070 if current trends continue. The Business-as-Usual (BAU) projection serves as a reference, and Tirunelveli's GHG emissions is projected to increase from 0.73 million tCO2e by in 2021-22 to about 2.18 million tCO2e in 2070.

The Progressive Action scenario, which aligns with existing national and state policies, aims for a 55.5% reduction in emissions by 2070 compared to BAU. This scenario focuses on enhancing energy efficiency in buildings, integrating renewable energy, promoting electric vehicles, and improving waste management infrastructure.

The Net-zero Pathway scenario outlines the ambitious actions needed to achieve net-zero emissions by 2070, targeting an 83.9% reduction in GHG emissions compared to BAU. Key actions include making all lighting and fans energy-efficient, constructing green buildings, and ensuring that at least 50% of electricity consumption comes from renewable sources. The scenario also emphasizes electric vehicles and comprehensive waste management solutions.

Climate Goals and Strategies

Tirunelveli's vision for a Net-zero Climate Resilient Future: To contribute to India's fight against climate change, and to lead as example for all non-metropolitan cities in India by transitioning towards a net-zero emissions future and building climate resilience of the city in the face of increasing climate risks from flooding and heat waves. Tirunelveli city aims to enhance its resilience to extreme rainfall and heat events through improved planning and management, infrastructure development and by adopting climate sensitive and nature-based solutions.

This Net-zero CRCAP suggests strategic measures focusing on mitigating GHG emissions, enhancing urban climate resilience, and addressing challenges like urban heat, flooding, and natural resource pressures. The key initiatives include constructing energy-efficient buildings, adopting a circular economy approach for zero waste, improving water and wastewater management practices, promoting zero-emission mobility, and developing blue-green spaces to safeguard natural ecosystems, ensure good air quality, and enhance citizen well-being.

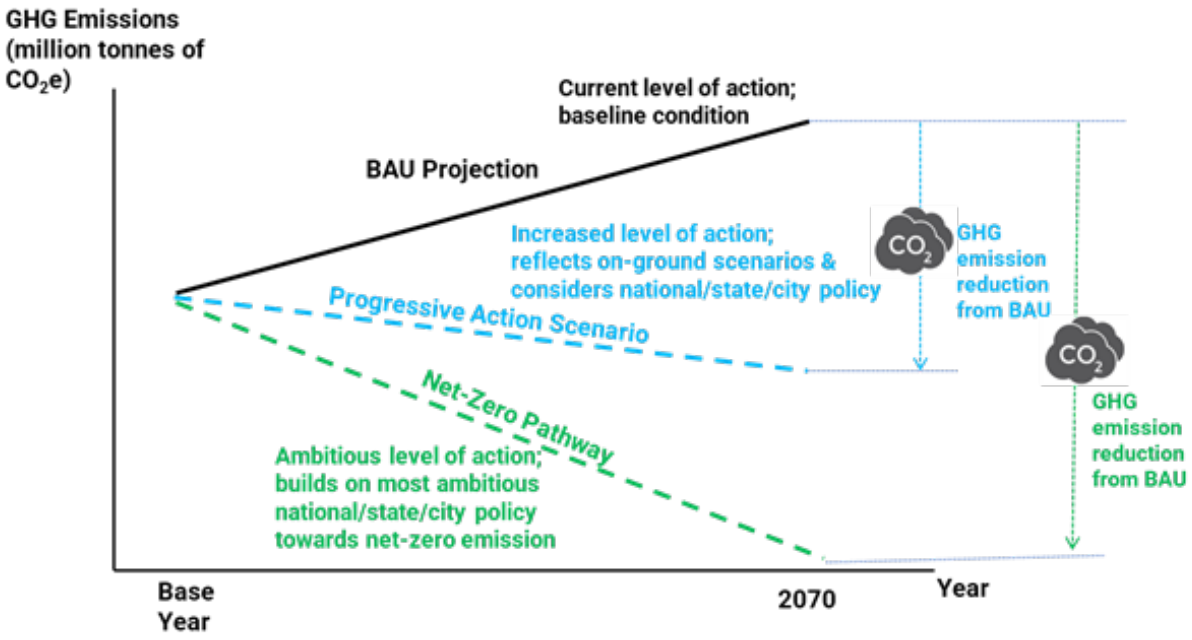


Figure E.5: Electricity consumption from municipal operations (2021-22)

Sector	Built Environment and energy	Transport	Water Supply
Goals	Transition to an energy efficient and heat resilient city by adopting low-emission strategies for the built environment.	Encourage development of zero-emission transport infrastructure and adoption of clean mobility options	Augment water resilience of the city and reuse 100% of treated wastewater to meet commercial and industrial water demand.
Targets	Up to 80% of new buildings adopt green building principles by 2070. 100% energy efficient lighting and fans in new and existing buildings Up to 65% of energy demand met by RE	Shift 8% of motorised trips to public transport and 10% to NMT by 2070. Shift 90% of all vehicles to low-emission vehicles by 2070.	90% adoption of energy-efficient equipment for water supply and 40% of energy demand to be met by RE sources Reduce NRW to 15% by 2050 and 10% by 2070.
Strategies	Encourage use of green building principles to design thermally comfortable and high-performance buildings. Mandate targeted energy performance measures and green building standards for buildings. Transition to a clean powered local grid to meet the city's energy demand.	Develop NMT (biking and walking), infrastructure and improve efficiency of public transit. Encourage adoption of low-emission mobility options and development of RE powered transport infrastructure. Integrated planning and development of transport infrastructure and adoption of smart traffic management systems.	Frame local policies and rules for water conservation. City-wide coverage and 24X7 water supply through an efficient water distribution network with reduced NRW. Undertake ecological restoration of lakes and Thamirabarani riverfront to enhance water resilience of city. Equip water supply network with energy efficient systems powered by RE.

Waste Water

100% treatment and reuse of wastewater generated in the city

90% adoption of energy-efficient equipment for wastewater infrastructure and 60% of energy demand to be met by RE sources

100% new plants use anaerobic treatment with methane gas capture and reuse.

City-wide coverage of sewerage network; Equip wastewater collection network and treatment facilities with energy efficient equipment powered by RE.

Implement septage management measures to treat and recycle sludge to minimise environmental hazards.

Enhance operational and energy performance of wastewater infrastructure using energy efficient equipment and low-emission processes.

Storm Water

Increase resilience to urban flooding and riverine flooding during extreme rainfall events.

Increase coverage of stormwater drain network as per CPHEEO guidelines by 2050

Watershed management of natural drains in the city through sustainable urban planning practices to prevent urban flooding

Rejuvenation of lakes to enable them to act as flood buffers and natural groundwater recharge areas.

City-wide coverage of stormwater drainage network and implementation of nature-based solutions for stormwater management

Solid Waste

Transition towards circular economy by adopting measures to develop a zero-waste city.

Low-emission waste collection systems for 100% waste collection

100% scientific waste processing, treatment, and disposal by 2030

Promote circular economy practices to transition to zero-waste city by minimising solid waste generation and maximising reuse and recycling of waste.

Achieve 100% source segregation and develop decentralised waste recovery facilities.

Develop scientific waste processing and treatment facilities to minimise environmental hazards of waste management and disposal.

Urban Green Cover & Biodiversity

Rejuvenate urban natural ecosystems and increase green cover to enhance climate resilience of the city.

Maintain green cover in the city at existing levels by 2070 and increase dense tree canopy.

Rejuvenate existing natural ecosystems in the city and promote native species for urban green and biodiversity measures.

Develop blue-green infrastructure in the city and microhabitats to enrich local biodiversity.

Enhance carbon sequestration through urban greening measures.

Advancing towards Net Zero GHG Emissions through the Net Zero Pathway:

Tirunelveli needs to undertake ambitious actions as per the Net Zero Pathway to achieve substantial GHG emission reductions that will help achieve Net-zero emissions by 2070. By implementing the strategies outlined in the Net Zero Pathway, Tirunelveli can reduce 83.9% of GHG emissions compared to BAU. This is equal to a reduction of about 1.83 million tonnes of CO2e missions by 2070. The strategies and actions proposed in the Net Zero Pathway are deemed crucial to achieve net-zero emissions by 2070 but require significant financial investments supported by state and national government under various programs and missions.

The Net-zero Pathway helps reduce Tirunelveli's GHG emissions by 83.9% in 2070 compared to the BAU scenario. This corresponds to GHG emissions reduction of 1.83 million tCO2e by 2070.

The Net-zero Pathway results in the following levels of emissions reduction compared to BAU:
GHG Emissions in 2030: 43.2% lower than BAU
GHG Emissions in 2050: 58.9% lower than BAU
GHG Emissions in 2070: 83.9% lower than BAU

Table E.1: GHG emissions reduction by sector for Net-zero Pathway

Sector	2030		2050		2070	
	Emissions Reduction (Million tCO2e)	Emissions Reduction from Sectoral BAU Emissions	Emissions Reduction (Million tCO2e)	Emissions Reduction from Sectoral BAU Emissions (%)	Emissions Reduction (Million tCO2e)	Emissions Reduction from Sectoral BAU Emissions (%)
Residential Buildings	0.16	39%	0.36	62%	0.69	94%
Commercial and Institutional Buildings and Facilities	0.12	58%	0.26	73%	0.50	95%
Manufacturing Industries and Construction	0.01	15%	0.03	21%	0.07	27%
Transport	0.13	49%	0.22	57%	0.43	91%
Waste	0.05	44%	0.09	62%	0.14	71%
Total	0.47	43.2%	0.97	58.9%	1.83	83.9%

The ambitious initiatives and targets set forth in the Net Zero Pathway aim to reduce BAU emissions by 83.9% by 2070. To fully meet the net-zero target, the remaining 16.1% of residual emissions will need to be addressed by adopting evolving technologies and carbon sequestration solutions. TCMC will collaborate closely with key stakeholders and relevant departments to realize this net-zero vision by 2070.

Way Forward

Tirunelveli aims to achieve net-zero emissions by 2070 through several key strategies. These include:

1. **Climate Awareness and Capacity Building:** TCMC plans to engage the community with climate education programs, establish Climate Information Centres, hire relevant experts to support various local climate initiatives, and build capacity through training programs for city officials and local experts.

2. **Governance and Policy:** Tirunelveli will strengthen its climate governance by creating a comprehensive vision, forming dedicated departments, engaging volunteers, integrating climate-responsive urban planning into its development plans and by aligning local objectives to the state level policies and climate targets.

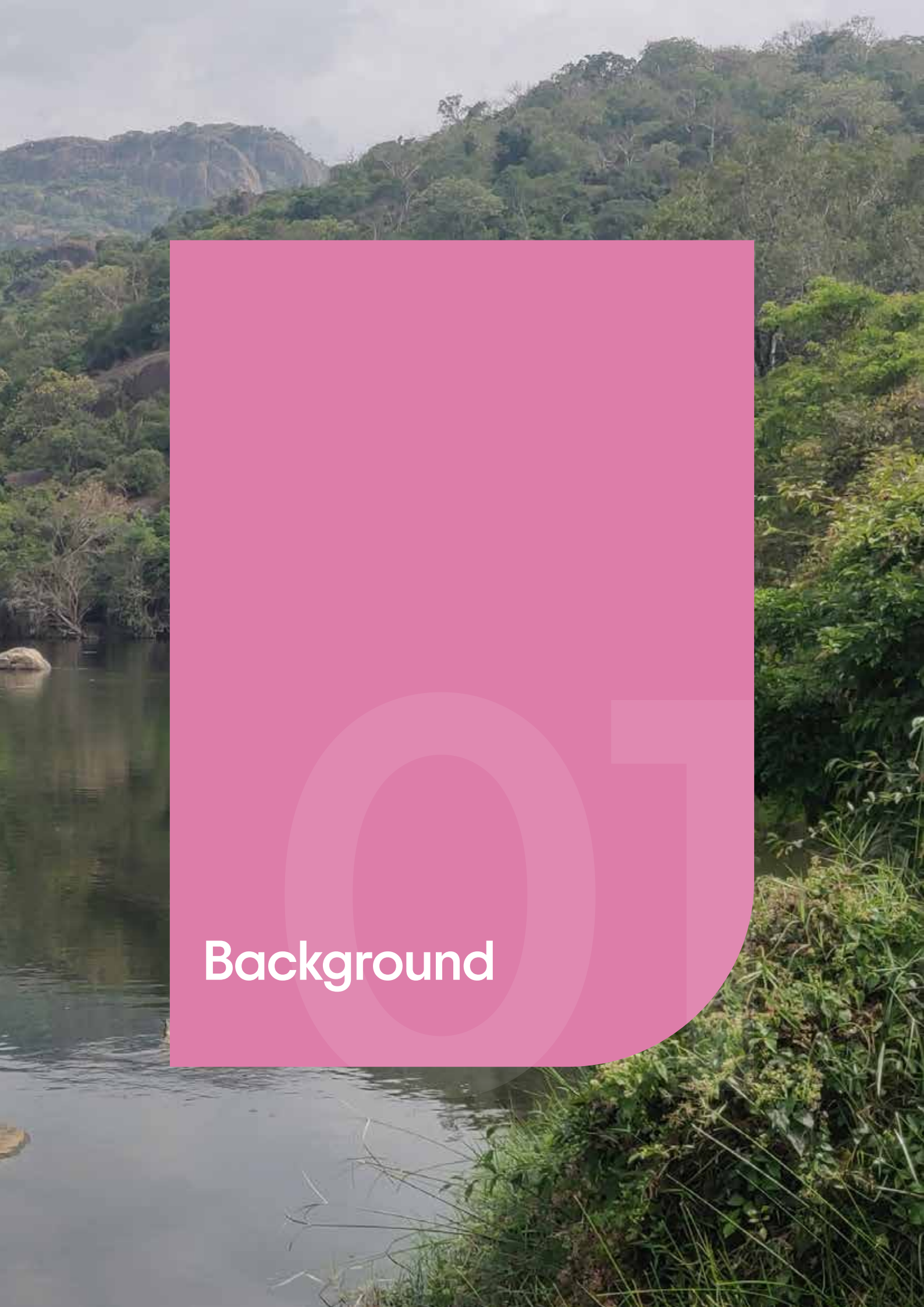
3. **Data Analytics:** To bridge gaps in climate data collection, TCMC will develop a climate data policy, invest in data infrastructure, and collaborate with research institutions to enhance data quality and analysis capabilities.

4. **Climate Financing:** TCMC will explore various financial instruments and innovative methods such as establishing a dedicated climate fund, leveraging public-private partnerships, exploring crowdfunding, and accessing international climate finance to fund its climate initiatives. This will be done in close collaboration with the Directorate of Municipal Administration (DMA), Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL), and other relevant organisations of Government of Tamil Nadu to raise climate finance for mitigation and adaptation projects in the city.

5. **Monitoring and Evaluation:** TCMC will establish a monitoring framework to track the implementation of climate actions, integrating these efforts with smart city infrastructure and using technology to improve efficiency. TCMC will also report nationally and globally on local climate actions to enhance visibility and disseminate learnings.

TCMC is committed to achieving the ambitious net-zero emissions target well before 2070, as pledged by GoTN. This Net-zero CRCAP is designed to steer Tirunelveli towards mitigating emissions and impacts of climate change while fostering local economic growth. Building on the city's legacy of being an educational hub in the region, TCMC will leverage the technological expertise of local talent pool to plan, implement and monitor climate actions to not only meet but exceed the targets set in this CRCAP which is aligned with state and national climate goals and targets.

TCMC believes that achieving a sustainable, climate-resilient future is a shared journey. As a non-metropolitan city with limited opportunities and modest socio-economic growth, TCMC aims to set a national and global benchmark for climate leadership by aspiring to achieve net-zero emissions ahead of schedule through bold and collaborative efforts with multiple sectors, engaging with a broad spectrum of stakeholders from government departments, private sector entities, non-governmental organisations, and the local community.



01 Background

1.1. Climate Change – An Existential Challenge to the Contemporary World

Climate change has long been recognised as a major threat to modern human societies and natural ecosystems in the world. Scientific evidence from extensive research on changing climate post industrialisation proves that climate change is an 'existential threat' to the contemporary world. If humans do not take major actions to slow climate change, then global temperatures are expected to increase by 4.4°C by 2100[1], which can be cataclysmic to Earth's living beings, lead to mass extinction of various flora and fauna species and pose a serious threat to human societies, especially from coastal communities and island nations.

Earth's climate change refers to the long-term shifts in its temperature and weather patterns, caused primarily due to human activities. Anthropogenic activities such as energy generation, industrial production, and transportation in the post-industrial era, centred around a fossil fuel-based economy dependent on burning of fossil fuels such as coal, oil, and natural gas, have led to emission of greenhouse gases (GHG) at an unprecedented rate. The earth's carbon cycle is unable to mitigate this increasing presence of GHGs at a given time in the atmosphere.

The greenhouse effect of excess carbon-dioxide (CO2) and other GHGs released into the atmosphere leads to gradual increase in temperature and is more commonly referred to as global warming, which has far-reaching consequences for the planet's living inhabitants. The scientific consensus is that emission of GHGs from human activities is the primary driver of climate change which caused global surface temperature to reach 1.1°C above 1850–1900 levels in 2011–2020[2].

The impacts of global warming are already being felt worldwide, such as the melting of glaciers and polar icecaps, which caused the global mean sea level to increase by 0.20 m between 1901 and 2018. Notably, the sea level rose rapidly at 3.7 mm per year between 2006 and 2018[3], and is expected to worsen in the coming decades with temperatures expected to rise beyond 1.5°C.

The global rise in temperatures and the resulting increase in mean sea level can have profound and detrimental effects on natural ecosystems and can disrupt climatic patterns, leading to more frequent and intense extreme weather events, such as heatwaves, hurricanes, cloudbursts, and droughts. The oceans have absorbed about 91% of the excess heat from GHG emissions[4], leading to ocean warming, more frequent marine heatwaves, ocean acidification, and reduced oxygen levels. These changes affect the marine ecosystems and the human communities dependent on them.

Beyond its severe impact on the ecological balance and environmental equilibrium, climate change exacerbates the risks from natural disasters by affecting various sectors of the economy, the food-water-energy nexus, and public health. In long-term this can lead to decreasing resilience of human societies and natural ecosystems against changing climate. Recognising the need for urgent and coordinated action against climate change across the globe, a 'climate emergency' has been declared by over 2,356 jurisdictions in 40 countries, including local governments[5].

The 2016 Paris Agreement, the 2030 Agenda for Sustainable Development, and the 2016 New Urban Agenda by UN-Habitat are key global frameworks for climate action and sustainable development. These frameworks emphasise the role of local governments in fostering a greener, climate resilient, and equitable future. The 2018 IPCC Special Report on Global Warming of 1.5°C states that the emerging climate resilient development pathways require implementation of local climate action in all cities and urban contexts to limit global warming to 1.5°C[6].

It identifies that the requirements for built environment, spatial planning, infrastructure, energy services, and mobility in growing cities, especially from South Asia and Africa in the next three decades, present crucial mitigation, adaptation, and development opportunities for achieving the global warming limit

[1] IPCC AR 6 2023 Intergovernmental Panel on Climate Change: Climate Change 2023: Synthesis Report. Accessed September 2023.

[2] Ibid.

[3] Ibid.

[4] Ibid.

[5] Climate Emergency Declaration. Accessed April 2024.

[6] IPCC 2018. IPCC 2018 Special Report on Global Warming of 1.5°C (SR1.5). Accessed September 2023.

of 1.5°C while ensuring sustainable socio-economic development of urban communities.

India is no exception to the impacts from changing climate patterns, with its average surface temperature having already increased by approximately 0.7°C[7] and continuing to rise. This warming has led to more intense, prolonged, and frequent heatwaves in recent years. The monsoon rainfall patterns, critical for India's water security and agriculture, have shifted in timing, intensity, and distribution. Indian summer monsoons are expected to become more intense with further warming, with potential drying during the late summer growing season, which could adversely affect agriculture.

Additionally, India's extensive coastline faces severe threats from the gradual rise in sea levels, which will impact coastal communities, including major cities of Chennai, Kolkata, and Mumbai. These significant impacts of changing climate underscore that the climate emergency is a pressing reality for India and addressing these challenges will require comprehensive adaptation and mitigation strategies at various levels of governance to protect vulnerable populations and ensure sustainable economic development.

1.1.1 Indian Cities Leading the Way in Meeting the Climate Goals of India

India, reinforcing its commitment to the climate crisis, set a target for net-zero emissions by 2070 at the 26th meeting of the 'Conference of the Parties' (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) held at Glasgow in 2021[8]. India also updated its Nationally Determined Contribution (NDC) under the Paris Agreement, aiming to reduce the emissions intensity of its GDP by 45% by 2030 from 2005 levels while meeting 50% of its electricity demand with non-fossil fuel based generation[9]. Additionally, the mission LiFE (Lifestyle for Environment) unveiled at COP-26, represents a global movement promoting environmentally conscious lifestyles to bring about positive behavioural changes at both individual and community levels across seven thematic areas, contributing to a sustainable future. India's updated NDC captures that this vision of LiFE, a citizen centric approach, is key to combat climate change.

The rapid urbanisation of the Indian demography necessitates that cities and smaller municipal agglomerations engage in sustainable development planning and integrated actions across energy, housing, water, waste management, and transportation sectors to ensure that the projected urban population is living in a sustainable and equitable society that meets the aspirations of citizens on desired quality and standard of living. Indian cities can play a leading role in climate action by developing and implementing strategies and programs, and integrating climate actions across sectors into their urban development paradigm.

India's National Mission for Sustainable Habitat (NMSH), one of the eight climate missions under the National Action Plan on Climate Change (NAPCC), aims to promote sustainable urban development by integrating climate action into urban planning and management. Its primary goals are to reduce GHG emissions and enhance climate and disaster resilience of Indian cities and towns.

Government of India's (GoI) flagship programs like the Smart Cities Mission, AMRUT (Atal Mission for Rejuvenation and Urban Transformation), and the Swachh Bharat Mission-Urban (Clean India Campaign) being implemented in the urban areas of the country have spurred climate actions in recent times, complementing India's climate commitments; have enhanced urban governance; and fostered the development of liveable and sustainable cities through innovative technology and facilities.

To transition the transportation sector of India towards low carbon and electric mobility, the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME-India) Phase II scheme under the National Mission on Electric Mobility encourages progressive induction of electric and hybrid vehicles into the transportation sector.

The new Solar Rooftop Scheme announced by GoI in the budget for 2024-25 aims to achieve 40 GW of solar rooftop PV capacity by providing subsidies up to 40% of the cost through Direct Benefits Transfer (DBT) to people for installing rooftop solar panels in their residences. This will further decarbonise transportation by providing clean electricity for charging private electric vehicles (EVs) at the

[7] IMD. 2022. Statement on Climate of India during 2022. Accessed September 2023.

[8] PIB. 2021. National Statement by Prime Minister Mr. Narendra Modi at COP26 Summit in Glasgow. Accessed September 2023.

[9] PIB. 2022. Cabinet approves India's Updated Nationally Determined Contribution to be communicated to the United Nations Framework Convention on Climate Change. Accessed September 2023.

household level.

The Ministry of Housing and Urban Affairs (MoHUA) launched the Climate Smart Cities Assessment Framework (CSCAF) in 2019 to guide 100 smart cities towards climate-responsive development. CSCAF allows cities to report and assess their climate actions against relevant parameters. Integrated into the Urban Outcome Framework (UOF) in 2022, CSCAF helps build a transparent, comprehensive database to track socio-economic and sustainable development in Indian cities and inform evidence-based policymaking. The framework serves as a guideline for local planning and implementing climate actions to address climate change.

Several states and cities in India are actively contributing to the nation's climate ambitions outlined in the NAPCC. Tamil Nadu, a leader in renewable energy (RE), particularly in wind and solar power, and the city of Tirunelveli, through its various local initiatives, are among those leading the charge in responding to India's ambitious national goals for achieving net-zero GHG emissions and advancing Sustainable Development Goals (SDGs).

1.1.2 Tamil Nadu – State level Policy Framework and Climate Change Mission

Tamil Nadu state, located in the extreme south of the Indian subcontinent, is a coastal region surrounded by the Indian Ocean to the east and south and flanked by the states of Kerala, Karnataka, and Andhra Pradesh from the west to the north along the Western and Eastern Ghats. The Western Ghats effectively blocks much of the rain bearing clouds of the Southwest monsoon from entering the state, making Tamil Nadu a water scarce state dependent extensively on the Northeast monsoon season from October to December. Therefore, the state is sensitive to monsoon failures and changing climate patterns.

Tamil Nadu, with a coast spanning about 1,076 km, is also sensitive to coastal weather conditions such as storms and cyclones. Historical evidence suggests high probability of increase in the frequency and intensity of climate related natural disasters in the state, thus making Tamil Nadu more sensitive and vulnerable to climate change and its impact.

Tamil Nadu's State Action Plan for Climate Change (TNSAPCC), initially developed in 2014 for 2015-2020, aimed to reduce the state's climate vulnerability by tailoring the NAPCC missions to the state's context. It included adaptation and mitigation strategies based on a thorough assessment of climate impacts and vulnerabilities across various sectors, outlining implementation roadmaps for state departments. To align with India's updated NDCs submitted in 2021 and prepare long-term plans up to 2030, the TNSAPCC was revised on the advice of GoI. The draft TNSAPCC 2.0 re-evaluates state-specific climate impacts, risks, vulnerabilities, and updates the climate adaptation and mitigation actions.

The TNSAPCC 2.0 has identified 10 focus areas for climate action in the state: Sustainable Agriculture & Allied Sectors, Water Resources, Forest and Biodiversity, Coastal Area Management, Strategic Knowledge & Climate Literacy, Disaster Management & Mitigation, Enhanced Energy Efficiency & Solar Mission, Health & Sanitation, Sustainable Habitat & Green Mobility, Gender and Climate Change, and Children and Youth for Climate Action. The TNSAPCC 2.0 will play a key role in implementing the SDG agenda, contributing to India's NDCs at the state-level.

Given the unique challenges of climate change faced by Tamil Nadu and its potential impacts, the state government of Tamil Nadu understands the importance of climate policies and action planning in its fight against climate change. Tamil Nadu showcased its vision and leadership in the fight against climate change by becoming the first state in the country to launch a dedicated Tamil Nadu Climate Change Mission (TNCCM), along with 2 other missions, the Green Tamil Nadu Mission (GTNM) and the Tamil Nadu Wetlands Mission (TNWM).

The goal of TNCCM is to support climate resilience actions and sustainable development in the state by adopting integrated strategies, planning and policymaking, with climate change as its centre. On the other hand, GTNM and TNWM will complement the objectives of TNCCM by striving to increase green cover in the state and by preserving the existing wetland ecosystems crucial to conserving the state's biodiversity.

The Government of Tamil Nadu (GoTN) has established the Tamil Nadu Green Climate Company (TNGCC) as a Section (8) Not-for-Profit Company to oversee the implementation of the three missions. TNGCC acts as a Special Purpose Vehicle (SPV) to address climate challenges in the state under the Department of Environment, Climate Change & Forest (DoECCF). The TNGCC has formed a specialised Project Management Unit (PMU) in collaboration with the Tamil Nadu Infrastructure Fund Management Corporation Limited (TNIFMC) to facilitate DoECCF in implementing the

three missions. A dedicated Tamil Nadu Green Climate Fund (TNGCF) has been setup by GoTN to support the activities of TNGCC.

Although DoECCF will execute the missions, TNGCC will facilitate the engagement of academia, private sectors, and civil societies. Its aim is to transition the state towards climate-friendly practices, promoting RE, sustainable infrastructure, agriculture, forest management, and resilience to climate impacts.

1.2 Tirunelveli's Climate Journey

Tirunelveli city is situated on the banks of Thamirabarani River that originates from the Western Ghats and drains into the Bay of Bengal in the Southern part of Tamil Nadu. The city has a rich cultural heritage and has been the epicentre of urbanisation and development in the Southern districts of Tamil Nadu beyond Madurai. Tirunelveli city experiences a hot semi-arid climate with majority of its rainfall being received during the North-East Monsoon season between October and December. The annual average rainfall of the city is only around 669 mm (in 2022) as it is rain-shadowed by Agasthya hills in the Western Ghats. Despite low precipitation levels, the city faces flooding risks from Thamirabarani River following heavy rainfall in the River's upper catchment areas. The city also experiences urban flooding during cloudbursts or heavy rainfall due to poor urban planning and lack of adequate stormwater drainage network. In recent years, the city experiences heatwaves during the summer months, another climate risk for the city.

1.2.1 Climate Linked Initiatives of Tirunelveli City

The Tirunelveli City Municipal Corporation (TCMC) has always been sensitive to climate change impacts and has been supporting climate linked projects and initiatives in the city. TCMC supported the implementation of the "Integrating Urban Climate Guidelines through Clean Technologies (RE & EE) at the State and City level to build Sustainable Low Carbon Cities" project in 2012-13, under which a city specific low carbon action plan for Tirunelveli based on GHG emissions inventory for 2010-11 was prepared. The plan aimed at driving the city-level use of clean technologies through RE and energy efficiency (EE) initiatives that promote local low carbon development while addressing the increasing demand for energy which is expected to rise manifold in coming years.

Since 2016, TCMC has implemented various infrastructure and smart solutions to enhance governance and urban services in the city under various state and national level initiatives and schemes, including the national missions like the Smart City mission, Swachh Bharat Mission and AMRUT. Some of the climate linked actions implemented by TCMC in the recent years include:

Energy Efficiency & Renewable Energy: TCMC replaced conventional streetlights with energy-efficient LED lights under an ESCO model, completing the transition to smart LED lights by 2020 with support from the Smart City Mission. TCMC also implemented 260-kW rooftop solar PV system and a 5 MW ground-mounted solar PV plant to offset municipal energy consumption under smart city mission.

Water and Wastewater Management: TCMC has increased its water supply capacity through the Ariyanayagipuram headworks scheme and implemented a Supervisory Control and Data Acquisition (SCADA) system to manage water supply, enhance operational efficiency and reduce non-revenue water (NRW). TCMC is expanding the coverage of the Underground Sewerage System (UGSS) network, implementing DEWATS at sewerage outfall points in Thamirabarani River and developing a new Sewerage Treatment Plant (STP) using advanced technologies to manage the increased wastewater generated with growing population in the city.

Solid Waste Management (SWM): Under the guidance of the Swachh Bharat Mission and with support from state and national level schemes, TCMC implemented a biomethanation plant, and several decentralized micro-composting centres across the city for biological waste treatment and improvement of SWM. TCMC scientifically closed the old dumpsite at Ramayanpatti compost yard by compacting legacy waste spread over 40 acres and developed an eco-park on top of it. Bio-mining of legacy waste in the existing dumpsite was also undertaken and efforts are underway to achieve source segregation of waste through behavioural changes.

Urban greening: TCMC developed more than 90 green parks in the recent years under various schemes and piloted a Miyawaki urban forest near the eco-park developed over scientifically closed dumpsite at Ramayapatti. TCMC is also keen to increase the green cover in open spaces across the city to contribute to sustainability and increased green cover in the city.

The city responded actively to the CSCAF, a performance assessment of Indian cities on climate action and indicators, conducted periodically by the National Institute of Urban Affairs (NIUA) on behalf of MoHUA. TCMC also embarked on an ambitious plan to address climate change impacts in the city with support from the Capacity Building for Low-carbon and Climate Resilient City Development (CapaCITIES) Phase II project in the last 4 years from 2020.

1.2.2 CapaCITIES Phase II Project in Tirunelveli

The CapaCITIES Phase II project, funded by the Swiss Agency for Development and Cooperation (SDC), India, aims to mainstream climate action in Indian cities and states by enhancing capacities to adopt integrated climate resilient planning, design innovative finance mechanisms and develop climate resilient infrastructure.

TCMC conducted a baseline assessment of its climate performance and prepared and implemented a simplified climate resilient city action plan (CRCAP). As part of its goal to achieve net-zero emissions status, TCMC planned to prepare and implement a Net-zero CRCAP in line with state and national climate goals and targets.

TCMC, with technical assistance from the CapaCITIES Phase II project, has developed this Net-zero CRCAP for Tirunelveli to guide the city towards sustainable and climate resilient development with net-zero GHG emissions goals. TCMC is also implementing a Flood Early Warning and Management System for Thamirabarani River with technical and financial assistance through the project.

To institutionalise continuing support to plan and implement local climate resilience measures in the city once active support from the CapaCITIES project ends, TCMC has formed a 'Climate Core Team' consisting of TCMC officials and a 'Stakeholder Committee' consisting of representatives from various associations, civil society organisations, and government agencies, led by the Municipal Commissioner.

1.3 Development of Tirunelveli Net-Zero Climate Resilience City Action Plan

1.3.1 Tirunelveli's Vision on Climate Resilience

Through collaboration and innovation, TCMC aims to cultivate a climate resilient community capable of thriving amidst climate change challenges and create a city that serves as an inspiring model for other non-metropolitan cities in India. The Tirunelveli Net-zero CRCAP positions Tirunelveli as a climate-conscious city keen to plan and implement local climate actions proactively in alignment with TNSAPCC and global frameworks such as the Paris Agreement and SDGs. The Tirunelveli Net-Zero CRCAP aims to mitigate GHG emissions in the city and bolster its urban climate resilience, with the goal of achieving net-zero emissions by 2070, and thus showcasing the transformative potential of sustainable practices and leading the way towards a brighter, more climate-conscious future.

TCMC envisions promoting climate-resilient urban planning and infrastructure development in the city as its economy continues to grow, stressing the importance of sustainable practices across all urban development sectors. The city is keen to plan and implement strategic measures and local actions to fortify its resilience to climate risks and challenges such as urban heat, flooding, and natural resource pressures, with a decisive shift towards a future with net-zero emissions while ensuring an equitable and sustainable urban environment.

To drive progress towards net-zero emissions, Tirunelveli intends to focus on constructing greener, energy-efficient buildings that prioritise thermal comfort and rely on clean, renewable energy sources. TCMC will also embrace a circular economy approach, aiming towards zero-waste, to minimise the impacts of the waste sector on the environment, while maximising resource efficiency. Committed to actively promoting zero-emission mobility, TCMC will enable cleaner transportation options for citizens. TCMC seeks to ensure citizen safety and enhance citizen well-being, by developing blue-green spaces to safeguard natural ecosystems and ensure good air quality and water resilience, and will develop sustainable infrastructure and deliver municipal services that are robust and climate resilient.

Tirunelveli's Vision for a Net-zero Climate Resilient Future: To contribute to India's fight against climate change, and to lead as example for all tier-3 cities in India by transitioning towards a net-zero emissions future and building climate resilience of the city in the face of increasing climate risks from flooding and heat waves.

Climate Change Adaptation Goal: Tirunelveli city aims to enhance its resilience to extreme rainfall and heat events through improved planning and management, infrastructure development and by adopting climate sensitive and nature-based solutions.

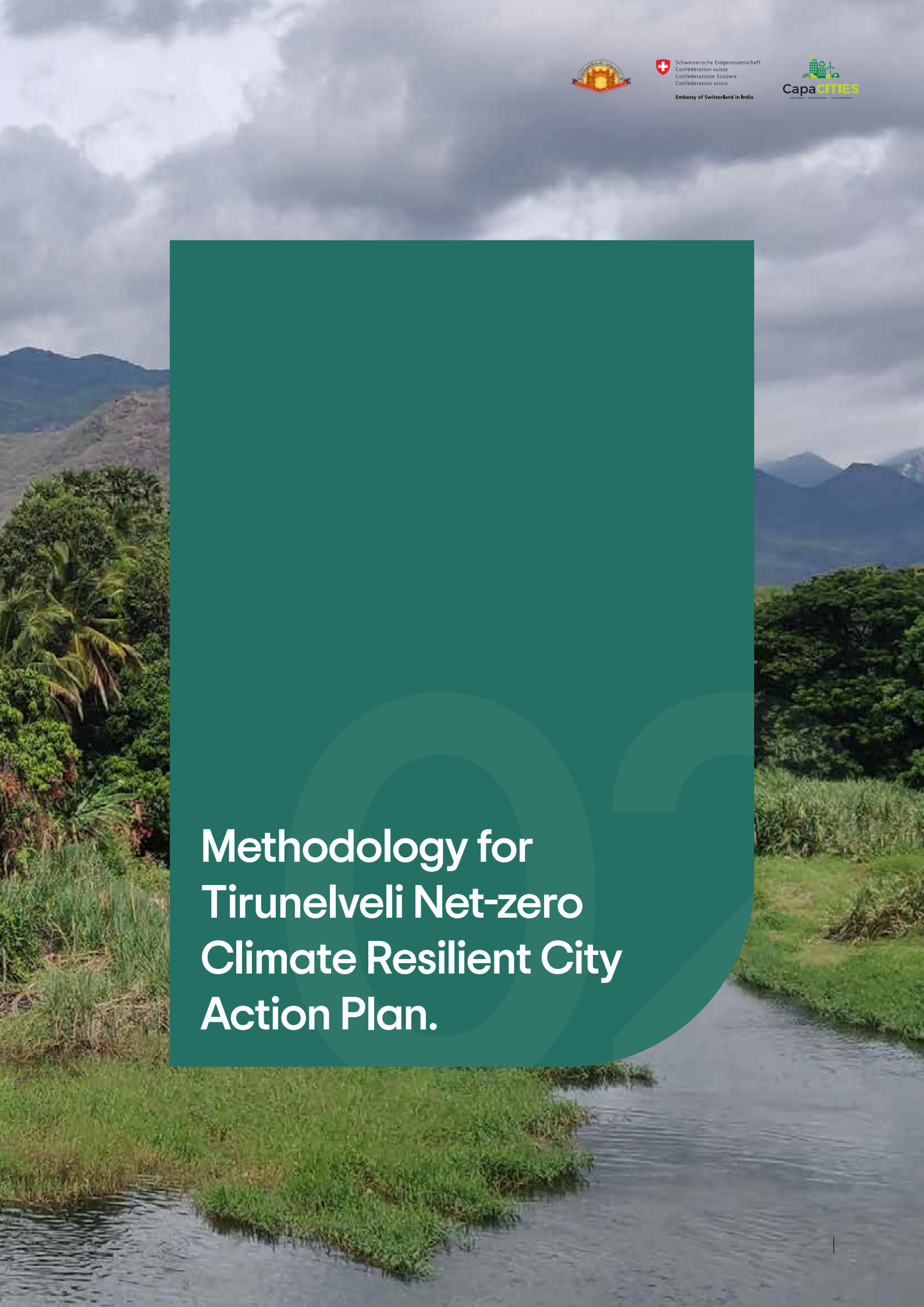
GHG Emissions Mitigation Target:

- **GHG Emissions in 2030:** 43.2%
- **GHG Emissions in 2050**: 58.9%
- **GHG Emissions in 2070:** 83.9%

Tirunelveli will update its net-zero targets during future revisions of this CRCAP and consider adoption of emerging technologies and strategies to achieve 100% GHG emissions reduction from Business As Usual (BAU) scenario by 2070 and to ensure the city's resilience to future impacts of climate change.

1.3.2 Methodology for the Development of Tirunelveli's Net-zero CRCAP

TCMC used the **"Net-zero Climate Resilient Cities Methodology"** developed by ICLEI South Asia to develop its CRCAP, aiming for net-zero emissions by 2070. This is a comprehensive 9-step structured process to develop the city's adaptive capacity to climate change and to mitigate emissions through locally tailored actions. The methodology follows global standards and protocols that offer thorough guidance to develop and implement a CRCAP in a city and is detailed further in Chapter 2 of this report.



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Embassy of Switzerland in India

CapaCITIES

Methodology for Tirunelveli Net-zero Climate Resilient City Action Plan.

The main approach of the **"Net-zero Climate Resilient Cities (CRC) Methodology"** involves securing commitment from local government leaders, setting up institutional frameworks, engaging stakeholders, assessing the local context, preparing GHG emissions inventories, assessing the climate risks and their impacts, identifying climate vulnerability of urban systems, identifying, and prioritising climate resilience measures, and developing the CRCAP.

Tirunelveli's Net-zero CRCAP developed using this process is aligned to Government of India's (GoI) 2070 Net-zero commitment at COP 26.

2.1 Overview of the Net-zero Climate Resilient Cities Methodology

The CRC methodology adopted for developing the Net-zero CRCAP for Tirunelveli includes nine steps, each with three actionable items, providing a comprehensive framework for assessing climate fragility and integrating climate-resilient options into urban development policies. Steps 1 to 4 focus on securing local government commitment, conducting research and assessments, setting baselines, and developing the action plan.

Steps 5 and 6 outline the necessary institutional arrangements and stakeholder engagement for CRCAP implementation. Steps 7, 8 and 9 offer guidance on creating a sustainable implementation strategy, scaling up actions through collaboration at multi-governance level, reviewing and updating the CRCAP, and reporting local climate actions to gain recognition and attract climate investments.

Figure 2.1: ICLEI Net-zero ClimateResilientCities Methodology

Phase One: Analyse

Step 1: Commit and Mobilise

1.1 Secure Initial Commitment: Gain support from senior political and local government leaders to initiate climate-resilient development.

1.2 Set Up Institutional Structures: Form a Climate Core Team with representatives from all municipal departments to prepare and implement the action plan.

1.3 Identify and Engage Stakeholders: Involve key individuals, community representatives, and external groups to foster partnerships and promote ownership of the action plan.

Step 2: Research and Assess

2.1 Assess Country Context: Understand the impact of international, national, and sub-national policies on local climate resilience.

2.2 Assess Local Context: Conduct a self-assessment of local policy, governance, economic, social, and environmental contexts, and a baseline assessment of urban systems and services.

2.3 Climate Readiness Review: Evaluate the city's capacities and readiness to tackle climate change.

Step 3: Analyse and Set Baseline

3.1 Develop GHG Emissions Inventory: Determine GHG emissions sources in local government operations and the community using ICLEI South Asia's Harmonised Emissions Analysis Tool plus (HEAT+) tool, following the protocols outlined in the Global Protocol for Community-Scale GHG Emissions Inventories (GPC).

3.2 Identify Fragile Urban Systems and Climate Vulnerabilities: Examine urban systems to evaluate impact of climate change, and identify vulnerable areas and population in the city.

3.3 Compile Baseline Synthesis Report: Summarise climate fragility statements, carbon intensity, and overlaps in critical sectors from mitigation and adaptation perspectives.

Phase Two: Act

Step 4: Develop Net-Zero Climate Resilient Cities Action Plan

4.1 Identify Resilience Interventions: Identify priority resilience interventions by analysing GHG emissions sources and climate vulnerability of urban systems.

Step 4: Develop Net-Zero Climate Resilient Cities Action Plan

4.2 Screen and Prioritise Interventions: Conduct a SWOT analysis to evaluate the feasibility and applicability of potential solutions.

4.3 Set Targets and Approve CRCAP: Link interventions to existing initiatives and set performance indicators to monitor progress.

Step 5: Detail and Finance Projects

5.1 Detail Climate Action Programs and Projects: Develop detailed plans and financial models for priority projects.

5.2 Test and Demonstrate: Implement pilot projects to test new technologies and approaches.

5.3 Identify Financing Models and Secure Funding: Explore funding sources, including municipal budgets, grants, and private-sector investments.

Step 6: Implement and Monitor Locally

6.1 Develop Institutional Arrangements and Capacity: Build internal capacity and governance structures to implement the action plan.

6.2 Implement Programs and Projects: Execute projects according to timelines and adjust for changes.

6.3 Monitor and Report: Develop a monitoring and evaluation (M&E) framework to track progress and report on emissions reductions and adaptive capacity.

Phase Three: Accelerate

Step 7: Integrate and Collaborate

7.1 Collaborate Horizontally: Coordinate with neighbouring municipalities for regional strategies.

7.2 Collaborate and Integrate Vertically: Engage with higher levels of government for policy alignment and support.

7.3 Connect with Similar Cities Worldwide: Participate in global networks to share knowledge and experiences.

Step 8: Review and Upscale

8.1 Update Data and Review Assessments: Conduct regular reviews to refine climate action strategies.

8.2 Evaluate the CRCAP: Assess the effectiveness of the action plan and identify new priorities.

8.3 Revise the CRCAP: Update the plan to reflect evolving climate challenges and technological advancements.

Step 9: Report, Inspire, Advocate:

9.1 Report Achievements Globally: Share progress on national and global platforms to gain recognition and support.

9.2 Showcase, Inspire Others, and Gain Recognition: Participate in awards and recognition programs to inspire other cities.

9.3 Advocate for Local, Regional, and Global Action: Use various platforms to promote ambitious climate action worldwide.

2.2 Process of Tirunelveli's Net-zero CRCAP Development

City Commitment: TCMC, by signing a Memorandum of Understanding (MoU) in March 2021 with ICLEI South Asia, representing the CapaCITIES Implementing Agency; and the Government of Tamil Nadu (GoTN), represented by Directorate of Municipal Administration, specified its intent to develop a CRCAP for the city with focus on climate resilience measures to achieve net-zero emissions status by 2070 and sustainable development in line with national and state goals.

Institutional Structures: In 2022, TCMC instituted a Climate Core Team (TCC) and Stakeholder Committee for climate action, comprising 15 officials led by the Commissioner, signifying the city's commitment to embedding climate action within its developmental agenda. TCC meets as required but not less than once in 90 days (Annexure 2.1).

Stakeholder Engagement: Effective climate action planning involves consulting various groups, such as government agencies, NGOs, community leaders, university partners, and private sector organisations to ensure shared responsibilities and ownership. TCMC formed a Stakeholder Committee in 2022 to facilitate dialogue among TCC and other stakeholders who hold considerable influence in the socio-economic development of the city. This Committee, comprising 16 members from diverse sectors, played a crucial role in engaging stakeholders throughout the CRCAP development process (Annexure 2.1).

Urban Systems Baseline Analysis: A thorough evaluation of Tirunelveli's development context, socio-economic and environmental profile, and the status of urban infrastructure and service provision was conducted to develop a city profile and an urban systems gap analysis. This further aids in identifying climate vulnerabilities and high-emission activities within the city. The city profile and urban systems gap analysis are detailed and documented in chapters 3 and 4.

Climate Risk and Vulnerability Assessment: Based on the historical rainfall and temperature data from IMD, the future climatic trends were estimated to understand the vulnerability of the urban systems, water, wastewater, stormwater, solid waste, transport, and health services against climate risks like urban flooding and urban heat events. Vulnerable areas and vulnerable population impacted by climate risks were identified through analysis of quantitative data on urban system issues from the city's grievance redressal system and based on stakeholder consultations.

Based on the likelihood and consequences, the risks associated with all critical fragile urban systems specific to Tirunelveli were assessed based on qualitative inputs from stakeholders. The adaptive capacities of urban systems were also determined with inputs from stakeholders. Tirunelveli's Climate Risk and Vulnerability Assessment is detailed in Chapter 5.

GHG Emissions Inventory

Baseline Data Collection: GHG emissions baseline for Tirunelveli city was established based on city level data gathered on stationary fuel consumption, solid waste management (SWM), transport fuel consumption and electricity consumption across all community and local government sectors. Data collection efforts included engagement with departments of TCMC and external agencies, such as TANGEDCO, public sector oil & gas utilities like Indian Oil Corporation Limited (IOCL) to ensure comprehensive coverage. Identified data gaps were addressed through further inquiry and discussions with the respective agencies.

GHG Emissions Inventory Development: A comprehensive GHG emissions inventory was developed using the HEAT+ Tool and following the GPC. This included emissions from community-wide activities within TCMC jurisdiction and municipal operations in the city, including municipal buildings, street lighting, water supply and wastewater management facilities, SWM infrastructure, and the municipal vehicle fleet.

The GPC compliant GHG emissions inventory was developed for the fiscal years 2017-18 to 2021-22. The GHG emissions baseline considered for the preparation of the Net-zero CRCAP is 2021-22. The methodology of the GHG emissions inventory development and the results are presented in Chapter 6.

GHG Emissions Projection and Scenario Planning

GHG Emissions Projections: Future projections for energy consumption and GHG emissions of Tirunelveli city was undertaken for the short term (2030), medium term (2050), and long term (2070) to facilitate strategic planning for the future. The projections were based on population forecasts, and the socio-economic development anticipated for the city. ICLEI South Asia's Net-zero GHG Emissions Tool was used for the forecasting analysis. Specific GHG emissions reduction targets and priority mitigation strategies

were identified for two scenarios: 'Progressive Action' and 'Net-zero Pathway', aligning with Tirunelveli's climate goals and ambitions.

GHG Emissions Reduction Scenarios: 1) BAU Projection: This scenario illustrates GHG emissions levels under current climate action trajectories, assuming no additional reduction efforts beyond existing measures. 2) Progressive Action Scenario: Reflecting increased levels of climate action at the city-scale compared to the BAU projection, this scenario considers national and state government policies and local conditions. 3) Net-zero Pathway: Aligned with the GoI's commitment to achieve net-zero emissions by 2070, this scenario outlines the ambitious efforts required for Tirunelveli city to transition towards meeting net-zero GHG emissions targets. The GHG emissions forecasting and reductions from BAU estimates for each scenario are detailed in Chapter 7.

Development of Net-zero Climate Resilient City Action Plan

Determining Resilience Measures: Based on the assessment of GHG emissions sources and climate risks and vulnerabilities identified for each urban system, TCMC has identified mitigation and adaptation measures across sectors, considering their feasibility, impact, and alignment with ongoing projects and future plans.

Prioritising Resilience Measures: Through a thorough evaluation process, Tirunelveli has prioritised resilience measures for integration into the CRCAP, considering factors such as budget, scale, impact, duration, and alignment with other government policies and projects.

Establishing Targets and CRCAP Approval: The climate targets set in this Net-zero CRCAP align with climate ambitions and the net-zero targets set by GoI and GoTN. A formal approval by Tirunelveli's Municipal Council provides an opportunity for a political review, recommendations, and the adoption of the Net-zero CRCAP by the city's political leadership for necessary support.

The process followed by TCMC for development of the Net-zero CRCAP aligns with the first 4 steps of the Net-zero CRC Methodology outlined in Section 2.1. The subsequent steps include the follow up actions the TCMC will undertake to implement and monitor the climate resilience actions, to scale-up and achieve the set targets, and showcase it on national and international platforms. The next steps of TCMC are outlined below:

CRCAP Implementation and Monitoring

Tirunelveli will outline priority climate actions, establish timelines, and identify funding sources to support these initiatives.

TCMC will develop pilot projects to test innovative approaches and assess their effectiveness.

TCMC will explore multiple climate financing instruments, and identify funding sources, including municipal budgets, grants, and private-sector funding, to support its climate resilience projects.

TCMC will develop an institutional framework building up on the existing Climate Core Team to support its climate initiatives, and will focus on building local capacity, especially among the city government staff, to plan and implement local climate actions tailored for Tirunelveli.

Approved climate action projects will be implemented according to defined timelines and milestones and will be monitored through an M&E framework developed for Tirunelveli which will help the city track progress and quantify climate benefits.

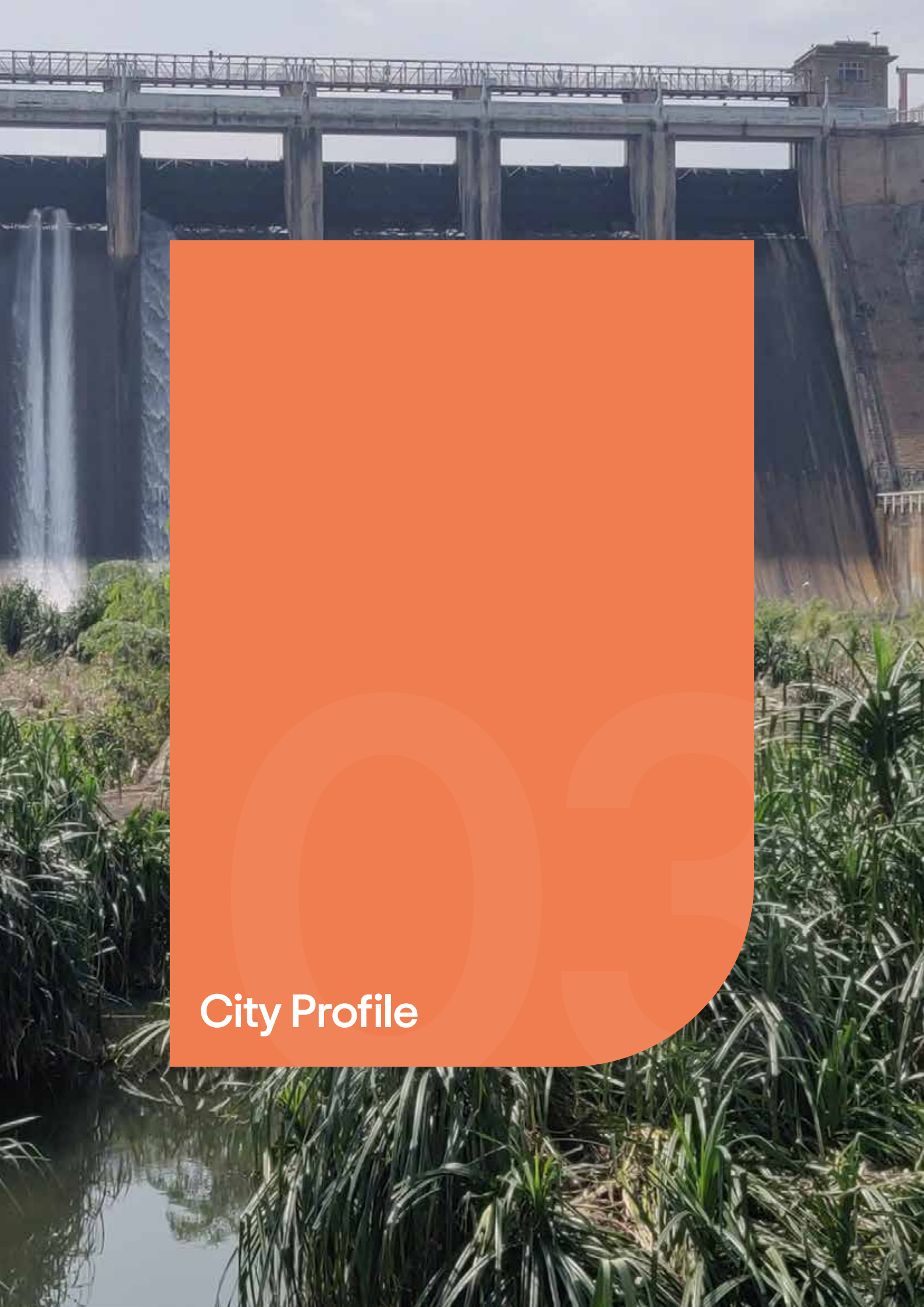
Collaboration, Scale-up and Reporting

TCMC will collaborate horizontally to develop a local ecosystem that can support its climate actions and enhance impact, while vertical integration with multiple levels of governance will help create a supportive policy and regulatory framework and develop tailored funding mechanisms for local climate actions.

Through global networks like the GCoM, the city will share experiences and learn from other cities' climate action efforts.

TCMC will conduct periodic review of baseline data and GHG emissions inventories and revise the CRCAP to refine the climate actions and strategies considering evolving climate challenges, emerging technologies, and new opportunities for action.

Tirunelveli will report its climate action achievements on national and global platforms to facilitate self-assessment and improvement, to gain recognition for exploring partnerships and garnering support for scaling up of actions, and to advocate for ambitious climate actions across nonmetropolitan cities worldwide.



City Profile

Figure 3.1: Location index map of Tirunelveli city.

3.1 Introduction

Tirunelveli, also known as Nellai, is the sixth-largest urban agglomeration in Tamil Nadu, India, after Chennai, Coimbatore, Madurai, Tiruchirappalli, and Salem, and serves as the administrative headquarters of Tirunelveli District. The Tirunelveli City Municipal Corporation (TCMC) was constituted on 1 June 1994, incorporating the adjoining municipalities of Tirunelveli, Palayamkottai, and Melapalayam, along with Thachanallur Town Panchayat and 15 other village panchayats, covering an area of 108.65 sq km. Tirunelveli city is divided into 4 administrative ones including Thachanallur, Palayamkottai, Melapalayam and Tirunelveli, encompassing 55 wards (Figure 3.1).

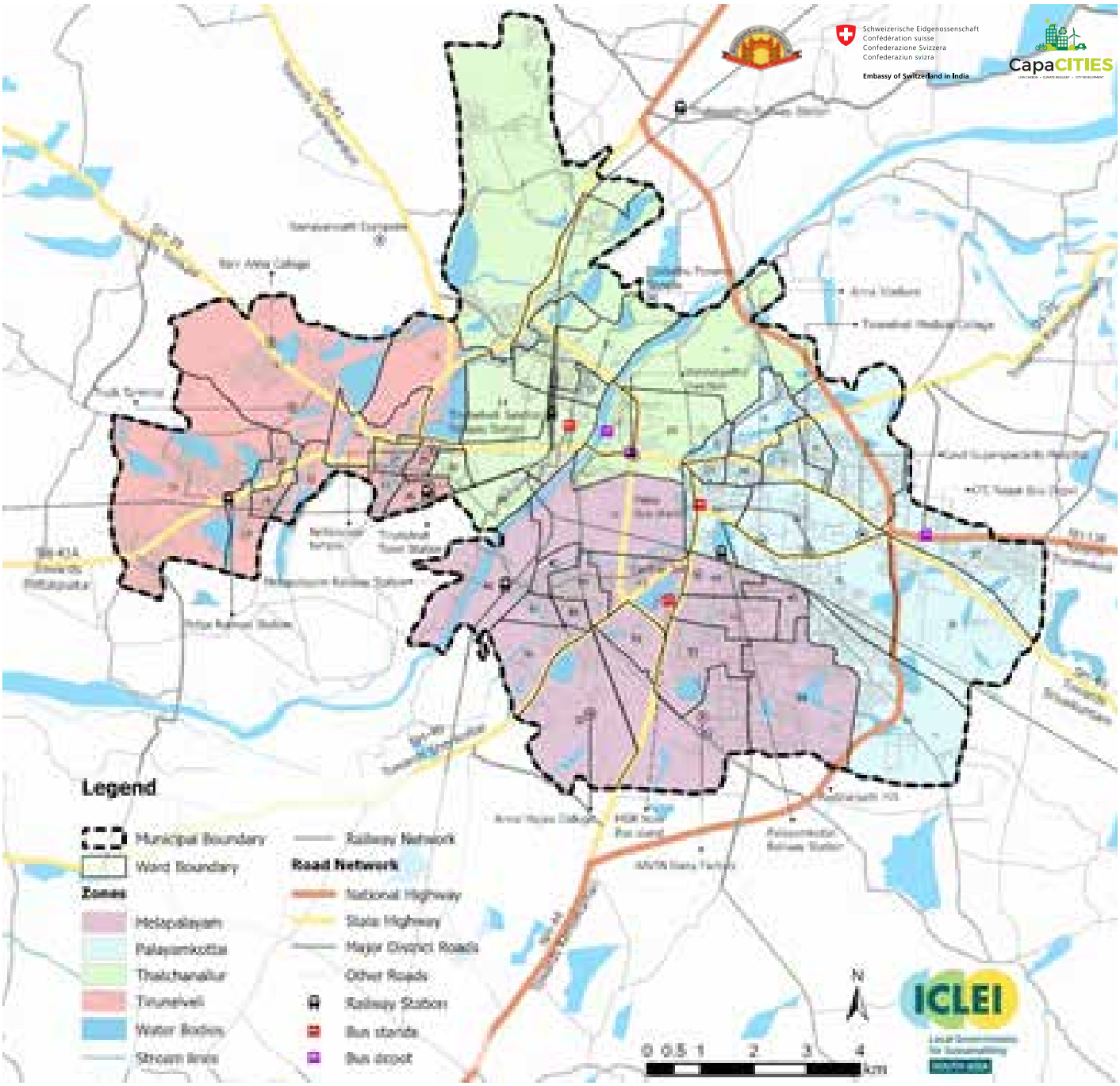


Figure 3.2: Administrative boundary map of Tirunelveli city
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

Table 3.1: Tirunelveli administrative divisions

Name of Zone	Wards Covered	Area (sq. km)	Population (2011)
Tirunelveli	15-27 (13 wards)	18.65	104,247
Palayamkottai	5-9, 32-39, 55 (14 wards)	23.16	119,141
Melapalayam	31,40-54 (16 wards)	33.59	144,987
Thatchanallur	1-4, 10-14, 28-30 (12 wards)	33.26	106,463

Nestled along the banks of the Thamirabarani River, the sole perennial river in Tamil Nadu, Tirunelveli city is bisected by its flowing waters, extending about 17 km within the city. The historic Tirunelveli town graces the west bank of the river, while its counterpart, the Palayamkottai town, resides on the east bank of the river. The city's economy is based on agriculture and allied activities, and serviced based industries. Tirunelveli's diverse industrial landscape encompasses administrative services, agricultural trade, tourism, banking, agricultural machinery, information technology, and educational services. Historically renowned as the "Oxford of South India," Tirunelveli city shines as a prominent hub for educational institutions, regional administrative offices, government agencies and private entities alike.

3.2 Connectivity

3.2.1 Road Connectivity

Tirunelveli city boasts excellent road connectivity with major cities in Tamil Nadu and neighbouring states such as Madurai, Chennai, Thiruvananthapuram, and Bengaluru. Serving as a crucial junction along National Highway (NH) 44, India's North-South corridor from Kashmir to Kanyakumari, Tirunelveli also enjoys seamless access to prominent cities and towns in neighbouring districts like Kanyakumari, Tenkasi, and Tuticorin via well-maintained NHs and State Highways (SH).

A comprehensive network of public and private buses, originating from Tirunelveli and neighbouring districts, traverses numerous inter-state and intra-state routes, facilitating Tirunelveli city's connectivity to various destinations within Tamil Nadu and beyond. Figure 3.3 depicts the road connectivity of Tirunelveli city and Table 3.2 lists the major roads.

3.2.2 Rail Connectivity

The Tirunelveli Railway Junction serves as a pivotal and well-established hub on the Southern Railway line, linking the city to major destinations across the southern region. It plays a vital role in facilitating both passenger and cargo transportation for several surrounding districts. The city is traversed by three important railway routes: the Madurai – Kanyakumari line, the Tirunelveli – Sengottai line, and the Tirunelveli – Tiruchendur line. While the railway line from Madurai to Kanyakumari has long been electrified, the electrification of the remaining two lines connecting Tirunelveli to Tiruchendur and Sengottai was completed by Southern Railways in 2022-23.

3.2.3 Air Connectivity

The closest airport to Tirunelveli is the Tuticorin regional airport, situated 30 km east of the city in Vaagaikulam, Tuticorin locale. However, due to infrastructure constraints and runway size, it primarily operates flights to Bengaluru, Chennai, and Coimbatore. Efforts are underway to expand the airport, including the construction of a new terminal building and extension of the runway, to accommodate flights to all domestic routes connecting major cities. Additionally, Tirunelveli city is conveniently accessible from the existing international airports at Madurai and Thiruvananthapuram, located 151 km and 160 km away respectively by road.

Table 3.2: Major roads connecting Tirunelveli city.

National Highways	State Highways
- NH 44 (Srinagar to Kanyakumari)	- SH 39 (Tenkasi Tirunelveli Road)
- NH 138 (Tirunelveli to Tuticorin)	- SH 40 (Tirunelveli Tiruchendur Road)
	- SH 41 (Sankarankoil Tirunelveli Road)
	- SH 41A (Tirunelveli Pottalpudur Road)
	- SH 75 (North and South bypass Road)

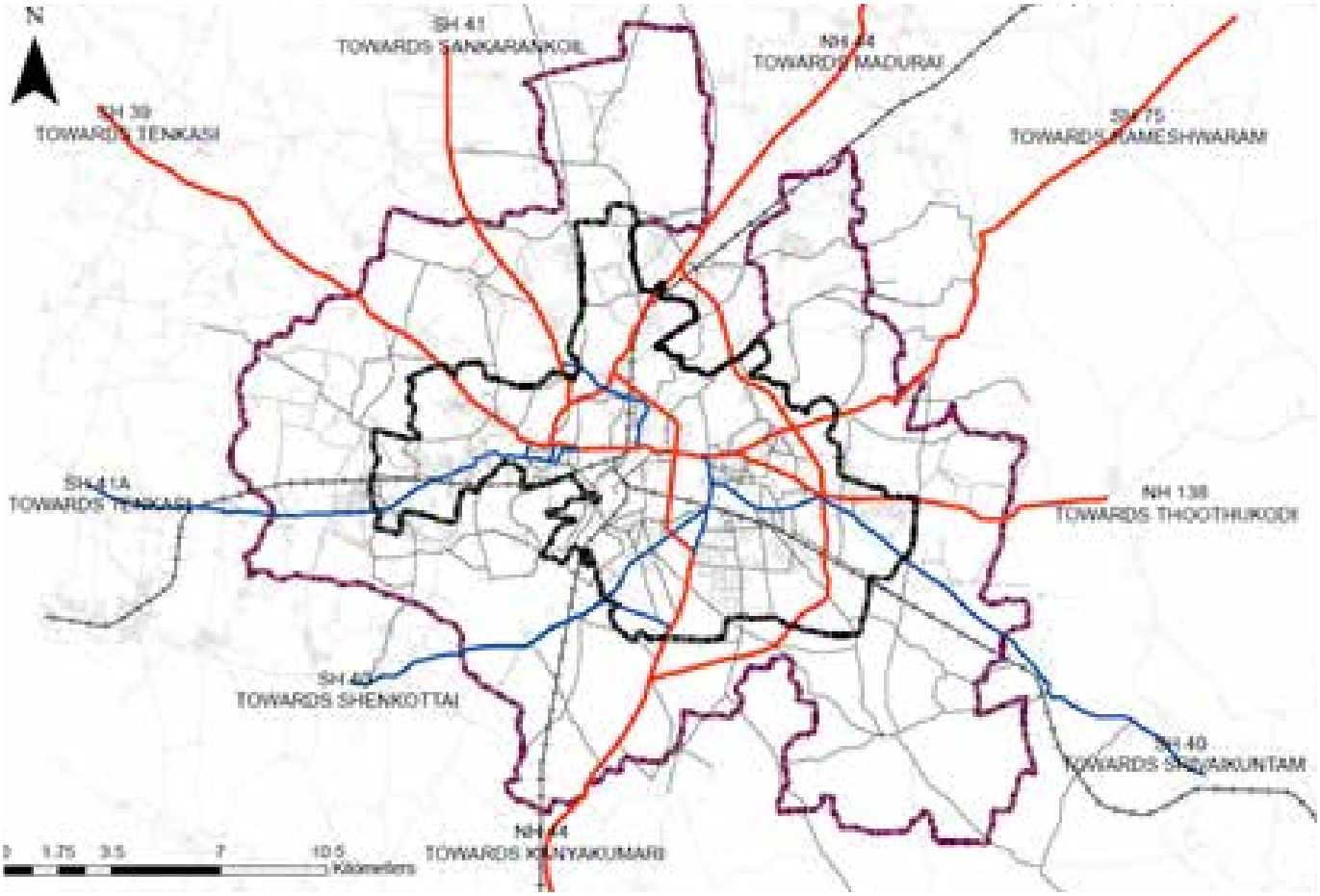


Figure 3.3: Administrative boundary map of Tirunelveli city
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

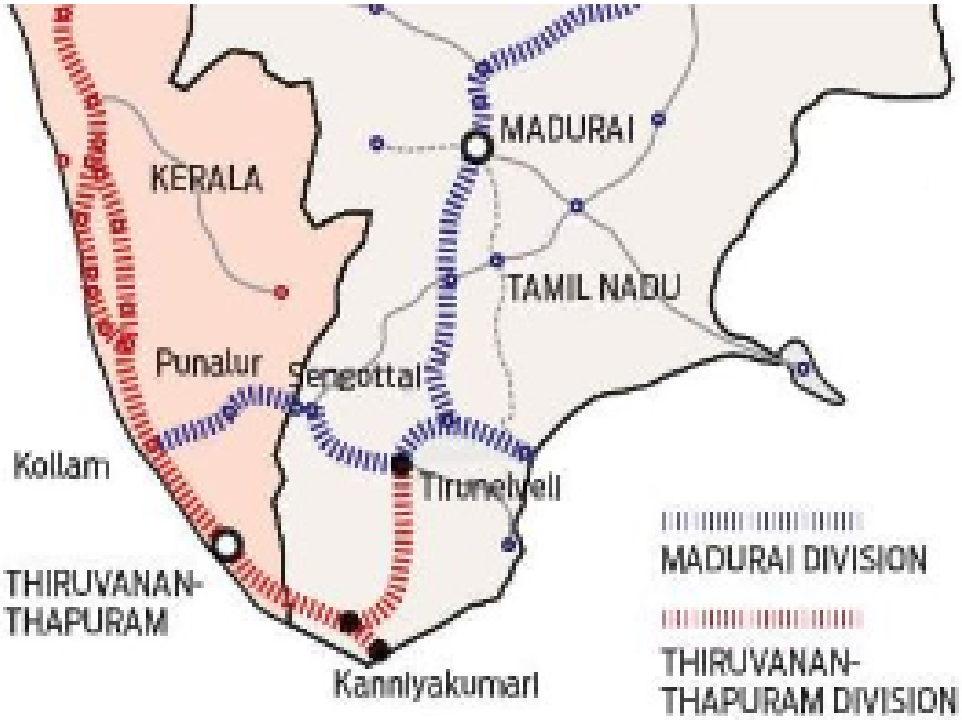


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Figure 3.4: Railway lines connecting Tirunelveli[1] Junction and Tirunelveli Railway Junction

[1] Source:https://www.newindianexpress.com/states/tamil-nadu/2017/Nov/27/railway-lines-in-tirunelveli-kumari-may-be-back-with-madurai-division-1711921.html; Accessed September 2023.

3.3 Demography

City Area (2021)	108.65 sq km
Population (2021)	554,522 (49.33% males and 50.67% females as per Census 2011)
Households (2021)	140,742 (with average household size of 3.94)
Population Density (2021)	5,104 persons per sq km (increased from 4,359 persons per sq km in 2011)
Slum Population (2021)	74,272 (68 notified slums and 56 non-notified slums)

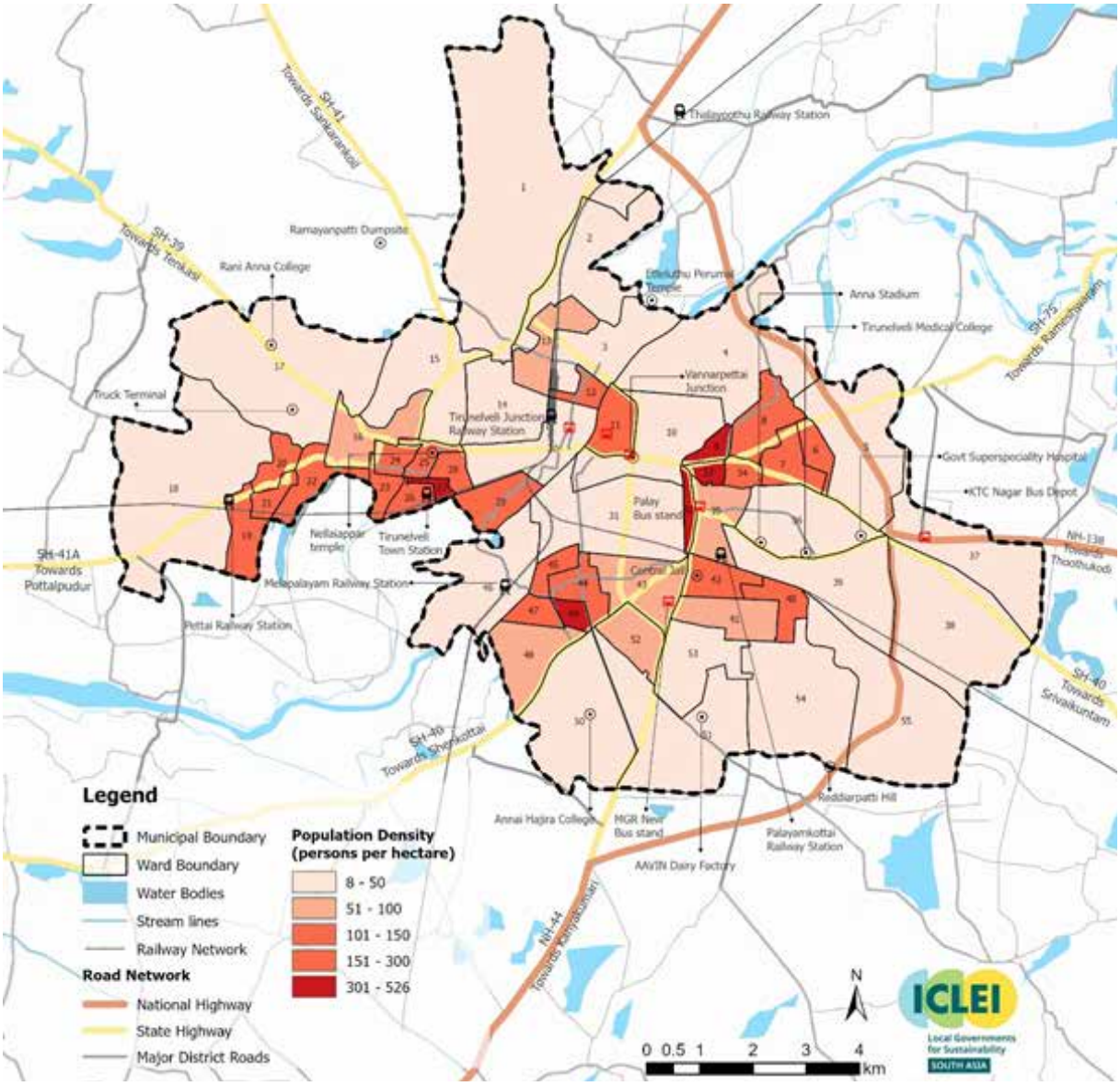


Figure 3.5: Population density map of Tirunelveli across wards.

[2] G.O.152, Municipal Administration and Water Supply Department (MAWS), Government of Tamil Nadu

[3] Tamil Nadu Housing and Urban Development Board (TNHUDB) data shared with TCMC.

3.3.1 Population Density in Tirunelveli City

Figure 3.5 illustrates the city's population distribution, revealing a noticeable skew, particularly attributed to the historically dense development in Tirunelveli's old town areas like Pettai, Palayamkottai market, Melapalayam town, and Thatchanallur town. Additionally, administrative wards such as 40, 41 & 42 located near the M.G.R New Bus Stand have experienced rapid growth in recent years, accommodating a significant population influx.

3.3.2 Population Projection for Tirunelveli

The projected population of Tirunelveli has been estimated using ICLEI's population forecasting methodology which has been adapted from the Shared Socio-economic Pathways (SSP) methodology of the IPCC Sixth Assessment Report (AR 6)[4]. Tirunelveli's population has been projected till 2071 considering three different urbanisation scenarios: slow, moderate, and rapid urbanisation.

For Tirunelveli, a slow urbanisation scenario for population projection is adopted, considering the city's anticipated socio-economic growth, and expected urbanisation patterns due to emerging industrial areas in the region and future employment opportunities.

Based on the historical trend of population growth in Tirunelveli, the estimated population projections were aligned with the Government of Tamil Nadu estimates of Tamil Nadu cities' population in 2021[5]. It is estimated that the projected population of Tirunelveli will reach 0.68 million by 2031, 0.85 million by 2051, and 0.97 million by 2071 (Figure 3.6), growing at an average decadal rate of 3.7%.

3.4 Economic Activities

Tirunelveli, a burgeoning urban centre, exerts influence over its district and neighbouring districts like Kanyakumari, Tenkasi, and Tuticorin. Notable as a religious hub in Tamil Nadu, its economy is primarily agrarian, complemented by rich mineral resources such as limestone and garnet sand. Tirunelveli district owes its agricultural success to the Thamirabarani River and its centuries-old irrigation system that enables cultivation of crops such as paddy, cotton, spices, groundnut, pulses, gingelly, coconut, chillies, and indigo. The palmyra palm, abundant in the area, serves as a vital raw material for various cottage industries.

Though still a part of the city's economic activities, cultivation of agricultural crops has seen a sharp decline since the turn of the century due to reduced water availability, encroachments, urban sprawl, and urban development activities. Patches of land in the northern, north-eastern, western, and southwestern parts of the city are still visibly being cultivated. The administrative wards in the city with significant area still under cultivation are 1, 2, 3, 4, 15, 16, 31, and 46.

[4] IPCC Sixth Assessment Report (AR 6); Accessed January 2024.

[5] G.O.152, Municipal Administration and Water Supply Department (MAWS), Government of Tamil Nadu

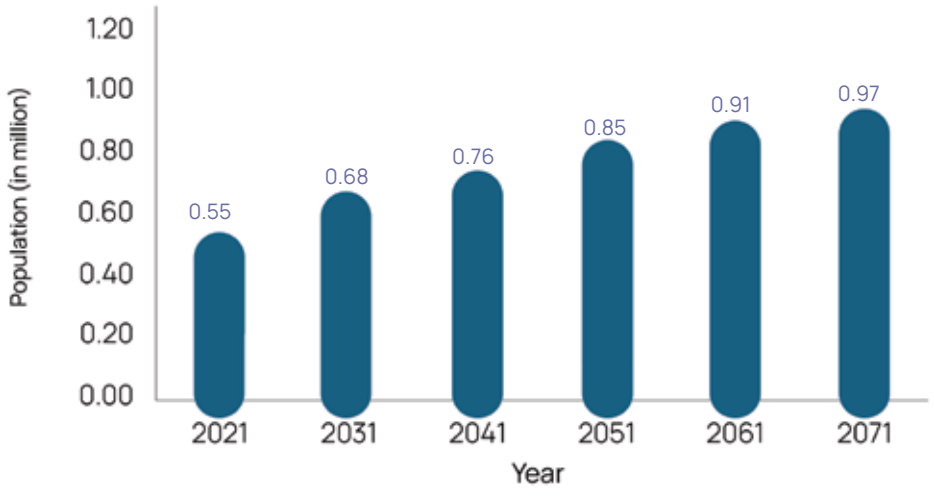


Figure 3.6: Projected population of Tirunelveli from 2021 to 2071

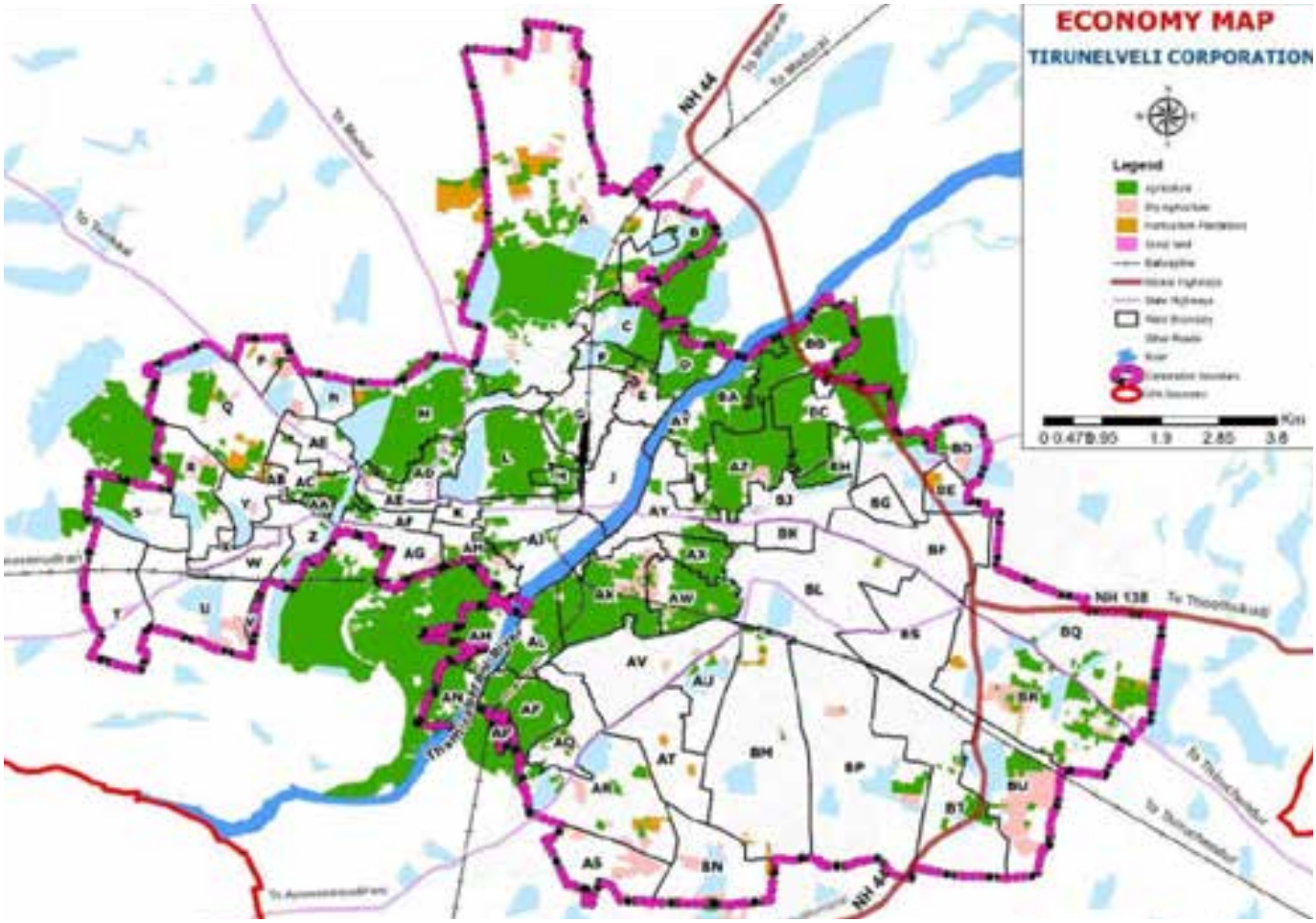


Figure 3.7 Agriculture map of Tirunelveli Corporation (2021)
Source: Tirunelveli Master Plan 2021, Tirunelveli Local Planning Area

The western part of the city hosts an industrial estate developed by Small Industrial Development Corporation (SIDCO) in Pettai, where the first cooperative spinning mill was established in 1958. The key products manufactured here include aluminium vessels, PVC pipes, corrugated boxes, and fabrication works. Mining industries and cement factories, benefiting from limestone and other mineral deposits in the region, dot the city's vicinity. There are around 25 medium and major industries such as cement, cotton yarn, sugar, rice bran oil, printing, flour mills etc., located in the existing industrial areas around the city.

Gangaikondan Special Economic Zone (SEZ), situated 15 km from the city, hosts a diverse range of industries, serving as a significant employment hub and an economic powerhouse for Tirunelveli. The State Industries Promotion Corporation of Tamil Nadu (SIPCOT) located at Gangaikondan SEZ, hosts manufacturing facilities for tyres, automobile spare parts etc., and a regional LPG bottling plant for Indane, largest in the state. Notably, TATA Power Solar (TP Solar), a subsidiary of TATA Power Company Limited (TPCL), is currently developing a 4 GW capacity Solar PV Cell and Module manufacturing plant in the SEZ, with additional job prospects and economic growth expected for Tirunelveli. Electronics Corporation of Tamil Nadu Limited (ELCOT) has also established an IT Park in the Gangaikondan SEZ for IT service-based industries.

The newly constructed trade centre at Tirunelveli under the Smart City Mission can be a key driver of economic development in the city by acting as a central trading hub for commercial activities. As a platform for businesses to converge and grow, the trade centre can attract local and national enterprises to promote trade, networking, and collaboration, fostering a vibrant economic ecosystem for the city. The trade centre can also host exhibitions, conferences, and business events, offering opportunities for knowledge exchange and business expansion.

Beedi rolling, safety matches making, mat weaving and processing, manufacturing of palm fibre and articles from palm trees, and hand loom weaving of textiles are the main household industries found in Tirunelveli city and its adjoining hinterland. Renowned local products include Korai mats, Kallidaikurichi Pappads, and Karukurichi mud pots.

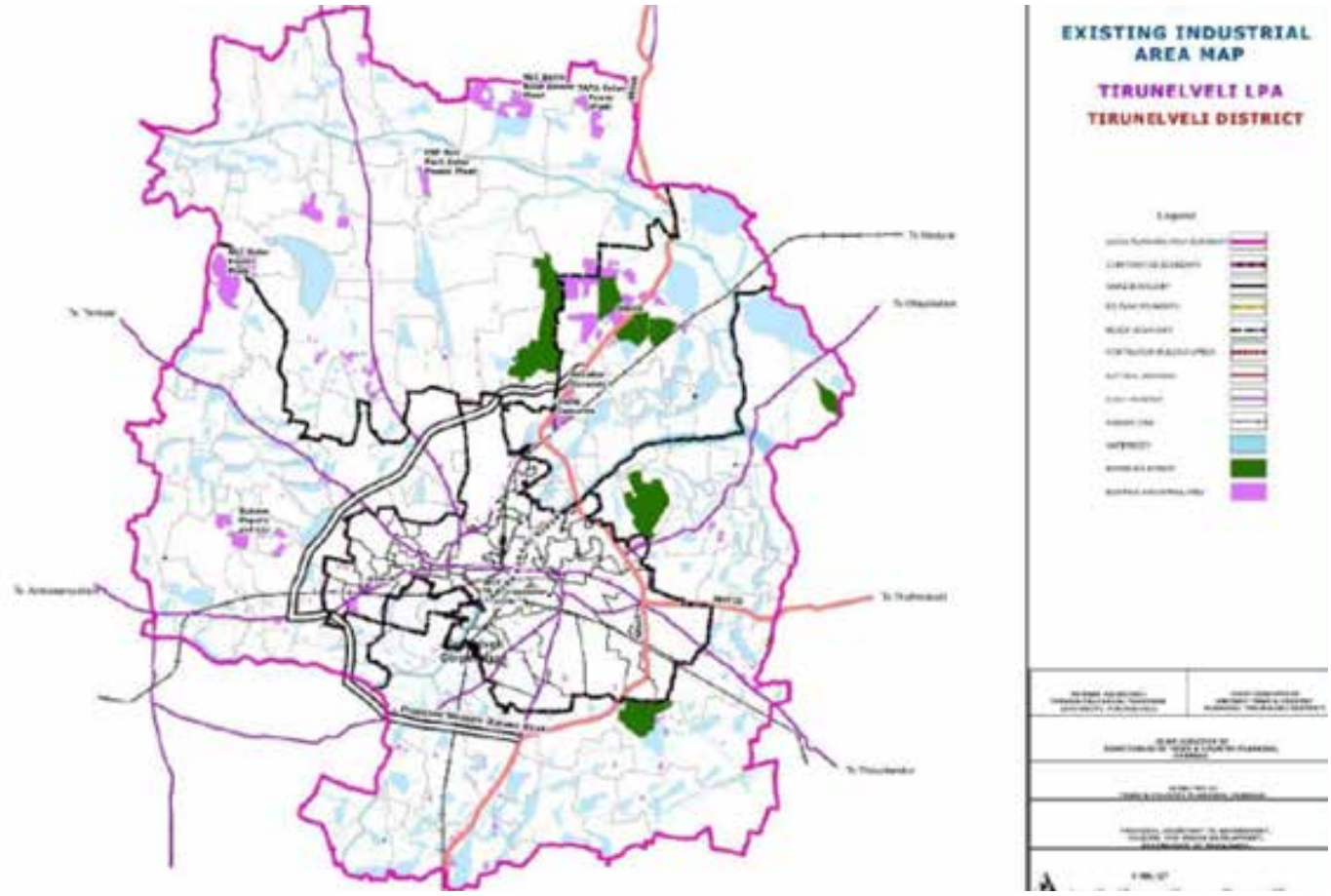


Figure 3.8 Existing industrial areas near Tirunelveli city
Source: Tirunelveli Master Plan 2021, Tirunelveli Local Planning Area

The city serves as a prominent educational centre in southern Tamil Nadu, boasting institutions like the Tirunelveli Medical College and Hospital, Veterinary College and Research Institute, Government Law College, and the Government College of Engineering. Managed by TCMC, there are 34 elementary schools, 5 middle schools, and 6 higher secondary schools. Additionally, numerous private educational institutions cater to the academic needs of the city's populace and the region. A sizeable portion of the white-collar workforce in Tirunelveli includes government officials, educators, and professionals employed in educational institutions. Moreover, the city offers a notably low cost of living compared to other major urban centres in Tamil Nadu.

3.5 Local Government Body

The city of Tirunelveli was established as a municipality in 1864 and later upgraded to municipal corporation status on June 1st, 1994, under the Tamil Nadu State Government's Tirunelveli City Municipal Corporation Act of 1994. The city was formed from amalgamation of the erstwhile Tirunelveli, Palayamkottai, and Melapalayam municipalities, the Thachanallur Town Panchayat, and several revenue villages including Alaganeri, Vellakoil, Senthimangalam, Palayapettai, Kariaiyiruppu, Thimmarajapuram, V.M. Chatram, Tharuvai, Melanatham, Karuppandurai, and parts of Kandiaperi, Rajagopalapuram in Nochikulam village panchayat, and Narasinganallur village.

The administrative boundary of TCMC consists of 55 administrative wards divided into 4 administrative zones, spanning an area of 108.65 sq km. The corporation's administrative structure is divided into the executive and political wings. The political wing comprises the elected municipal council, led by the Mayor and Deputy Mayor, who are elected by councillors from each administrative ward. Ward committee chairpersons, chosen by councillors, oversee administrative zones. Additionally, six committees, each with nine members, including at least 3 women, are established for decision-making, with the standing committee chairman elected by its members.

The executive wing, led by the Municipal Commissioner, oversees daily administrative functions, project implementation, and service delivery. The executive

wing serves as the chief executive authority and administration head. The team includes the Deputy Commissioner, City Engineer, City Health Officer, Assistant Commissioners for the 4 zones, and departments of planning, engineering, public health, personnel, revenue, and accounts, ensuring comprehensive city operations oversight. The executive wing's departmental structure and functions are explained below:

Engineering Department: Under the leadership of the City Engineer, this department oversees infrastructure maintenance and development, including roads, water supply, drainage, sewerage systems, and street lighting.

Public Health Department: Led by the City Health Officer, this department focuses on solid waste management (SWM), sanitation, birth and death registrations, vaccinations, disease prevention, and the operation of the public healthcare facilities including 10 Urban Primary Health Centres (UPHC) and associated Health Sub-Centres (HSC).

Town Planning Department: Managed by the Executive Engineer, this department is responsible for managing urban development and contributing to revenue generation strategies. The department is responsible for issuing building licenses, implementing development plans, enforcing urban planning, and building regulations, and overseeing land acquisition by TCMC for execution of development and infrastructure projects. At the zonal level, Assistant Commissioners are responsible for handling plan approvals and building permissions.

Revenue Department: Headed by the Assistant Commissioner (Revenue), this department is tasked with the collection of various taxes and charges from the residents and business entities within Tirunelveli city and plays a crucial role in ensuring a steady and sustainable flow of revenue, which is vital for the city's financial health and the implementation of public services and development projects.

Accounts Department: Supervised by the Assistant Commissioner (Accounts), this department handles financial matters, including management of the revenue, water supply & drainage, and education funds of TCMC, ensuring financial health and accountability.

Personnel Department: Operating under the Assistant Commissioner (Personnel), this department manages various tasks such as distributing official posts and couriers, handling all establishment duties including appointments, promotions, transfers, disciplinary actions, public grievances, council computerisation, issuing council resolutions, conducting local body elections and census work.

The organisation flow chart below describes the administrative functioning of TCMC:

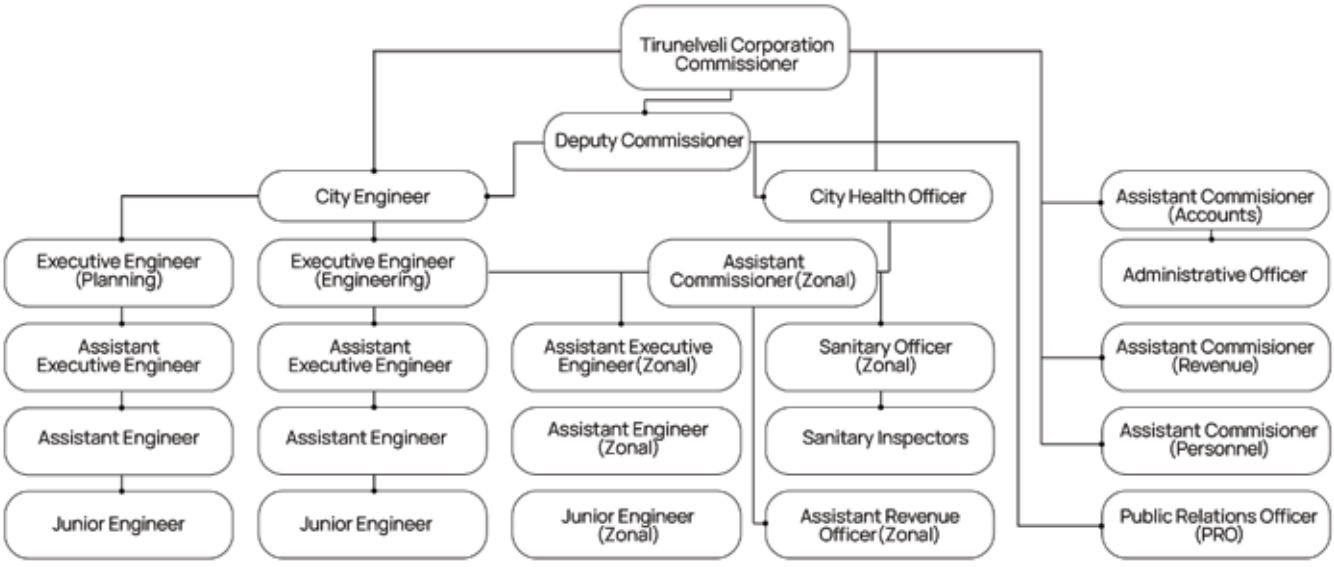


Figure 3.9. Organogram of Tirunelveli City Municipal Corporation

3.6 Land Use of Tirunelveli City

3.6.1 Existing land use of 2021 and proposed land use for 2041.

Tirunelveli city covers a total geographical area of 108.65 sq km (10,865 hectares). The city's unique spatial development history has emerged from the organic growth of four distinct urban centres, each contributing to its current urban structure. This urban development pattern has resulted in the emergence of sizable vacant plots, mostly undeveloped dry agricultural lands, adjacent to densely developed areas, presenting an opportunity to repurpose them for residential and mixed-use development. This will provide ample space to accommodate the expanding population and integrate essential urban service infrastructure.

Tirunelveli city is visibly expanding at a rapid pace eastward, particularly along NH 44 (Srinagar to Kanyakumari) and NH 138 (Tirunelveli to Tuticorin). The projected industrial expansion in the region, including the establishment of the ISRO Spaceport at Kulasekarapattinam, 55 km away from city; implementation of the Chennai-Kanyakumari Industrial Corridor project in the region, centred on SH 40 from Tiruchendur to Ambasamudram via Palayamkottai, Tirunelveli city; and expansion of the Tuticorin regional airport have long-term positive impact on socio-economic development of the region, and is poised to drive the development and growth of Tirunelveli city which is the largest urban agglomeration in the region. The previous Master Plan, formulated in 2005 and reconsented to by the Government of Tamil Nadu in 2010, outlined land-use allocation up to 2021. The Tirunelveli Local Planning Authority has now developed a new Master Plan for the horizon year 2041, with the final draft published for public feedback at present. According to the proposed land use outlined in the Tirunelveli Master Plan for the horizon year 2041, the portion of the city designated as undeveloped land, comprising agricultural areas, open spaces, and water bodies such as rivers, streams, and lakes, has notably decreased from 44% in 2021 to 23.76%. In contrast, the developed areas are primarily allocated for residential purposes (43.64%), followed by allocations for institutional (11.2%), transport (10.54%), commercial (9.03%), and industrial (1.82%) uses (Table 3.3).

The proposed land use plan for TCMC in 2041, compared to the existing land use scenario in 2021, presents a comprehensive vision for sustainable urban development. The key points highlighted in the master plan report are:

Residential Emphasis: Anticipating a rise in residential areas from 34.42% to 43.64%, the master plan aims to meet the growing housing demands within municipal limits, emphasising planned and inclusive residential development.

Economic Growth: Significant growth in commercial space (from 2.05% to 9.03%) and industrial land use (from 0.81% to 1.82%) signals a strategic approach to foster economic development and attract commercial activities, with dedicated zones planned for commerce and industry.

Institutional Infrastructure: Increased institutional areas from 8.53% to 11.20% indicate a focus on enhancing educational, healthcare, and public service facilities, aligning with the goal of improving overall quality of life and services for residents.

Transportation Networks: Maintaining a stable share of land for transportation (from 10.19% to 10.54%), the master plan underscores a commitment to sustaining and potentially enhancing existing transportation networks to ensure efficient connectivity within the municipal area.

Agricultural Transformation: A significant decrease in dry agricultural land (from 30.92% to 10.62%) reflects a shift in land-use policies, possibly towards urbanisation. The plan recognises the need to balance agricultural interests with urban development while safeguarding agricultural wetlands.

Table 3.3: Existing land use (2021) vs proposed land use (2041) of Tirunelveli city

Tirunelveli Land Use	Existing Land Use 2021 (sq km)	Existing Land Use 2021 (%)	Proposed Land Use 2041 (sq km)	Proposed Land Use 2041 (%)	Developable Area as per URDPFI (%)
Residential	37.40	34.42	47.42	43.64	36-39
Commercial	2.23	2.05	9.82	9.03	5-6
Industrial	0.88	0.81	1.97	1.82	7-8
Institutional	9.26	8.53	12.17	11.20	10-12
Transport	11.07	10.19	11.45	10.54	12-14
Open Space/Recreational	0.89	0.82	0.89	0.82	14-16
Agriculture	33.59	30.92	11.61	10.68	Balance
Waterbodies	13.32	12.26	13.32	12.26	
Total	108.65	100.00	108.65	100.00	

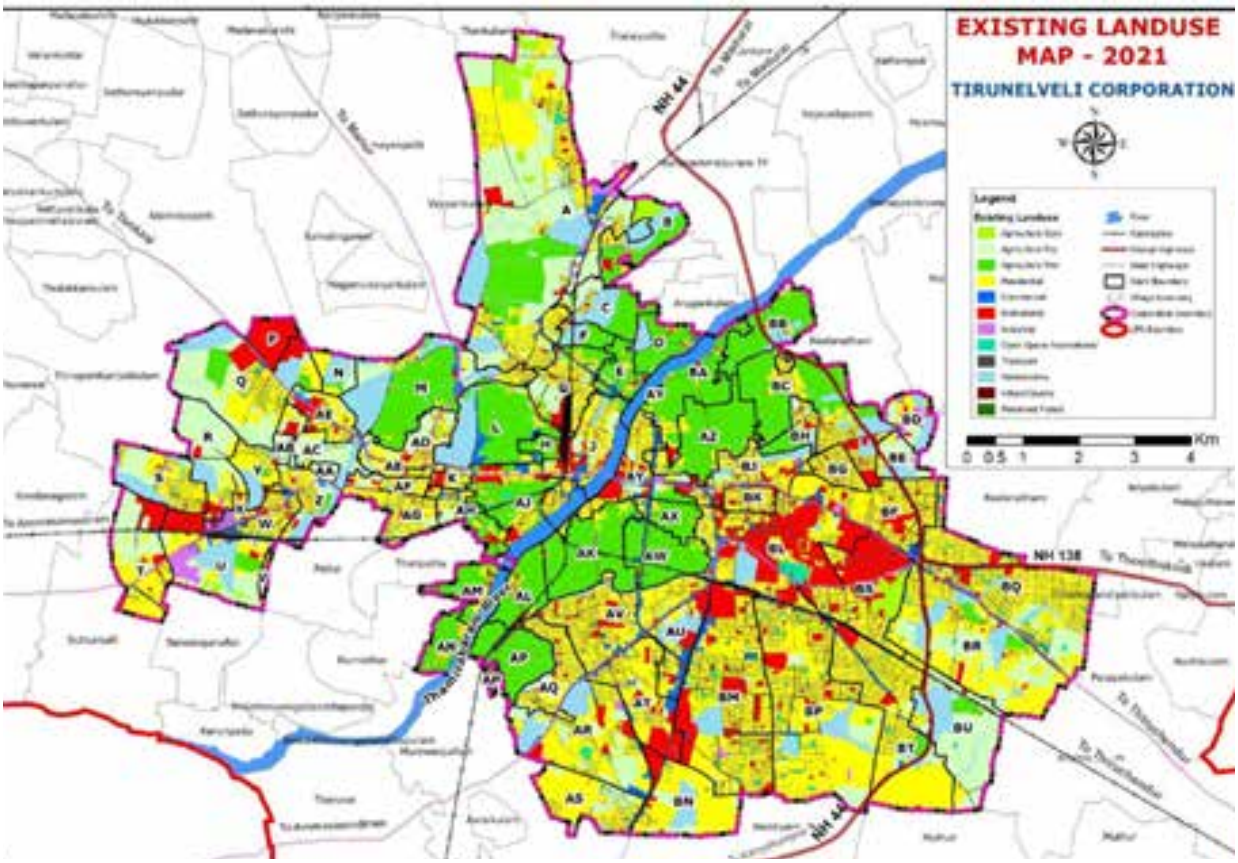


Figure 3.10: Existing land use map of Tirunelveli 2021
Source: Tirunelveli Master Plan 2021, Tirunelveli Local Planning Area

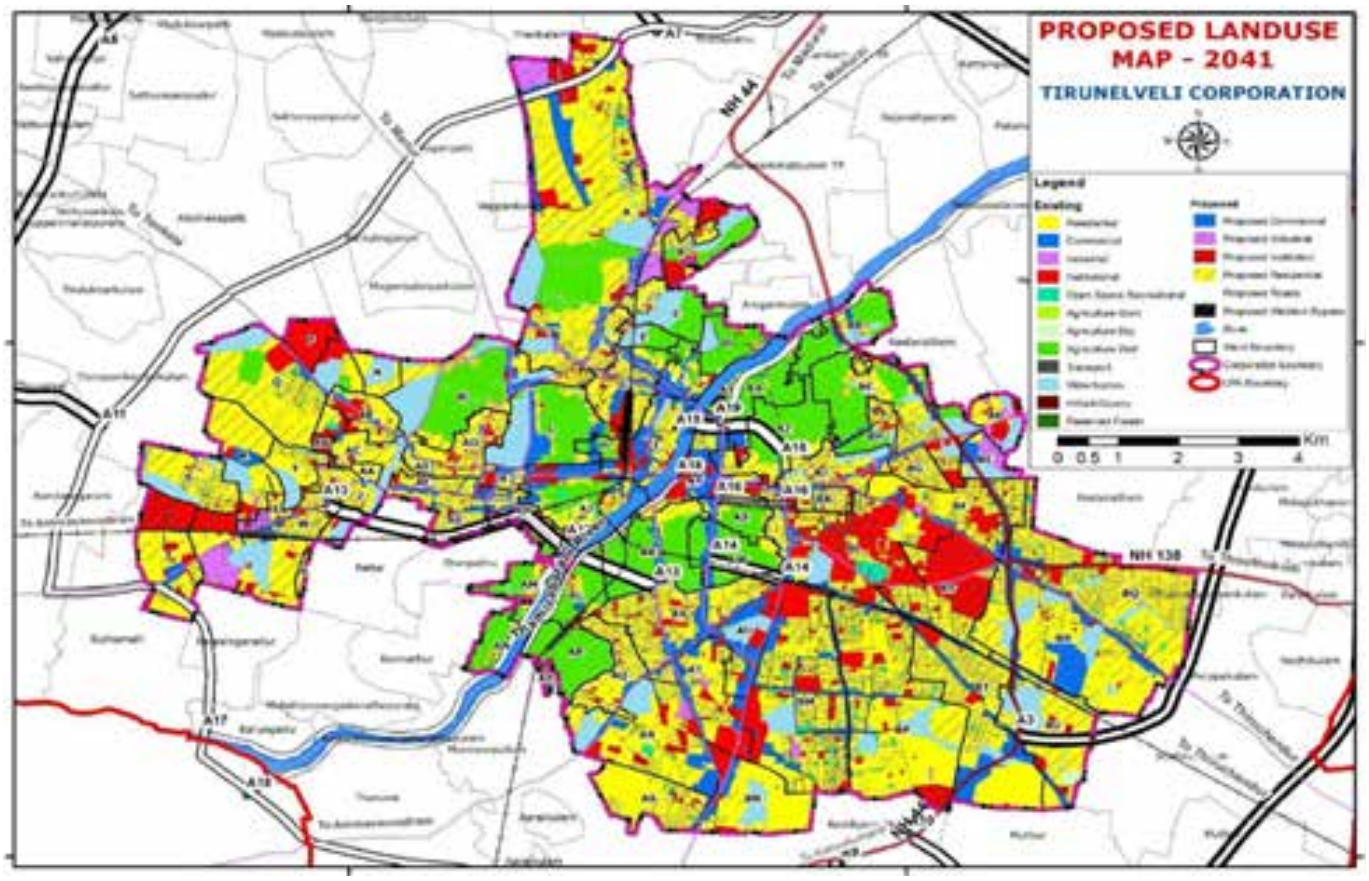


Figure 3.11: Proposed land use map of Tirunelveli 2041
Source: Tirunelveli Master Plan 2021, Tirunelveli Local Planning Area

3.6.2 Tirunelveli Land Use Land Cover Change in Recent Years

3.6.2.1 Methodology

The Land Use and Land Cover (LULC) map of Tirunelveli was generated using Sentinel-2A data, chosen for its accessibility and sub-10m composite resolution over multiple years. Cloud-free imagery from Sentinel-2A for the first week of February in 2019, 2021, and 2023 (specifically February 7, 2019, February 8, 2021, and February 12, 2023) was consistently available and thus used for mapping. After acquiring the imagery, preprocessing steps included atmospheric correction, orthorectification, and image quality enhancement.
Image classification was conducted using the 'Maximum Likelihood' supervised classification algorithm, following an adapted version of the United States Geological Survey (USGS) 9-step classification. Land was categorised into built-up areas, crops, roads, trees, bare ground, and water bodies. Training data, derived from ground truth information and existing maps, were employed to represent various land cover types across the city.

The classification results were validated using independent ground truth data or validation points, gathered through field observations and Google satellite images. Post-processing techniques were applied to refine the results, eliminating noise and misclassifications, generating the final LULC map.

3.6.2.2 Observations from LULC change assessment for 2019, 2021 & 2023.

The LULC change witnessed in Tirunelveli city was assessed for the years 2019, 2021 and 2023. Table 3.4 presents the results of the assessment.

Table 3.4: Area and percentage of various land use types over 2019, 2021 & 2023

Land Use Classification	2019		2021		2023	
	Area (sq km)	%	Area (sq km)	%	Area (sq km)	%
Built Area	27.33	25.15	28.78	26.49	30.12	27.72
Crop Land	26.31	24.22	25.22	23.21	23.56	21.68
Road	7.53	6.93	7.53	6.93	7.53	6.93
Tree cover	12.69	11.68	12.69	11.68	12.69	11.68
Bare Ground	28.52	26.25	28.16	25.92	28.48	26.21
Water Bodies	6.27	5.77	6.27	5.77	6.27	5.77
Tota Area	108.65	100	108.65	100	108.65	100

Key observations from the LULC change assessment are as follows:

- The built-up area in Tirunelveli expanded by 2.57% between 2019 and 2023, equating to a growth of 2.79 sq km. This growth reduces surface permeability, leading to increased runoff and potential flooding.
- The extent of water bodies remained constant throughout the period.
- Cropland area declined over the years, suggesting a shift in land use towards bare ground and built-up areas.
- Tree cover in the city remained stable at 11.68% over the study period.

3.7 Climatic Conditions of Tirunelveli

Tirunelveli city experiences a semi-arid climate, characterised by elevated temperatures during summer and moderate temperatures in winter. In May, the monthly average maximum temperature can soar to 38.4°C, while in January and February, it hovers around 22°C. April, May, and June are particularly hot, with temperatures peaking at 41°C (as recorded in May 2022). However, with the onset of the South-West monsoon in early June, temperatures begin to drop, reaching a comfortable level by October.

Located near the foothills of the Western Ghats, Tirunelveli is shielded from the South-West monsoon by the Agasthyamalai hills, resulting in most of its annual rainfall of 669 mm (as recorded in year 2022) occurring between October and December during the North-East monsoon.

Winds are light, blowing towards the North and West in the morning and towards the South and East in the evening.

During north-east monsoon season, the skies are often cloudy or hazy until the evening, followed by rainstorms. Humidity levels peak from October to December, reaching 80.8% in November, while it remains relatively low at 54.3% in May.

3.8 Soil

Tirunelveli city and its surrounding areas predominantly feature two types of soil: black cotton soil and river alluvial soil. Black cotton soil, found in Tirunelveli and Palayamkottai blocks, is ideal for cultivating crops like paddy, finger millet, and corn. Based on the hydrological soil group, black cotton soil is classified as class D, that is, it has high runoff and low infiltration potential.

Table 3.5 Monthly average minimum and maximum temperatures (2022-23)

Month	Avg. Max. Temperature (°C)	Avg. Min. Temperature (°C)	Humidity @ 2030 hrs (%)
Jun-22	35.3	27.5	55
Jul-22	32.6	26.6	62.6
Aug-22	32.4	26	65.8
Sep-22	33.2	25.5	65
Oct-22	33.2	25	69.7
Nov-22	30.7	24	80.8
Dec-22	32	26	65
Jan-23	30	22.9	76.2
Feb-23	31.7	22	73.4
Mar-23	34.6	24.3	69.2
Apr-23	36.2	24.5	66
May-23	38.4	27.9	54.3

Source: Tirunelveli Statistical Handbook, 2022-23

Table 3.6 Actual rainfall recorded at Tirunelveli city in 2022.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (in mm)	30	7	0	145	10	7	0	81	5	95	151	137	669

Source: IMD Rainfall Data from Palayamkottai station, Tirunelveli.

Therefore, the volume of water reaching the nearby waterbodies and streams will be higher in locations with this soil. Specially designed groundwater recharge structures are required in such locations to increase stormwater infiltration.

On the other hand, river alluvial soil is found along the riverbanks of Thamirabarani River that traverses the city. This type of soil is conducive to the cultivation of groundnut, chillies, and pearl millets. Based on the hydrological soil group, river alluvial soil is classified as class D and has moderate runoff and infiltration potential. Precipitation in this region contributes to both runoff and infiltration equally.

3.9 Air Quality

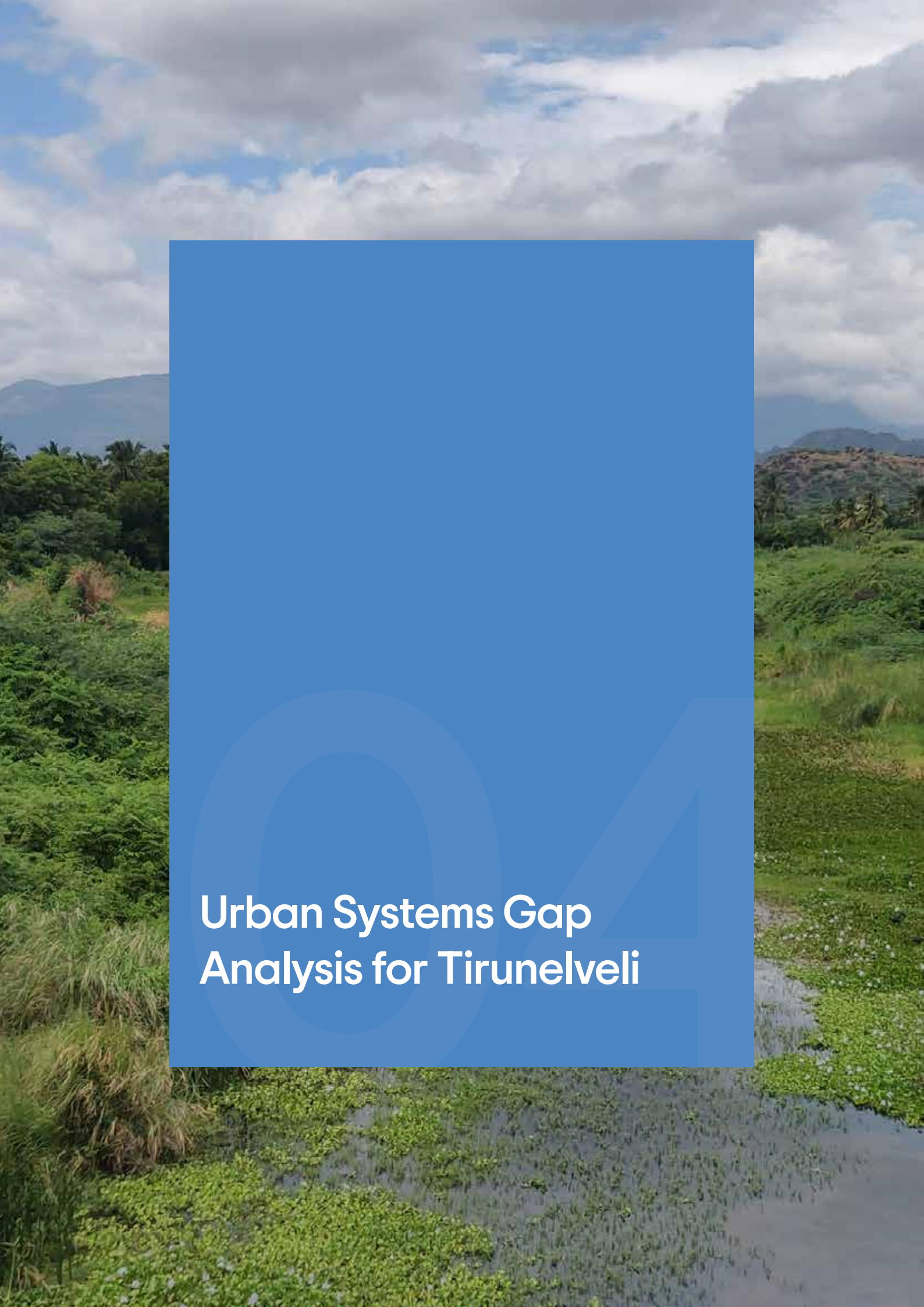
To monitor air quality in Tirunelveli, the Tamil Nadu Pollution Control Board (TNPCB) has implemented a Continuous Ambient Air Quality Monitoring system (CAAQMS) at the TCMC office. Table 3.7 shows the monthly average of pollutant concentrations from the CAAQMS station recorded for years 2022 and 2023.

From Table 3.7, it is evident that PM10 is the only pollutant that does not meet the National Air Quality Standards, while PM2.5 concentration is witnessed to be high only during December 2022 and January 2023.

Table 3.7: Average monthly ambient air quality of Tirunelveli from 2021 to 2022

Year	Month	PM2.5 (µg/m3)	NO2 (µg/m3)	CO (mg/m3)	PM10 (µg/m3)	SO2 (µg/m3)
2022	January	14.66	3.19	1.15	87.05	21.36
	February	10.87	2.53	0.38	90.94	14.41
	March	15.03	4.77	0.62	53.19	19.08
	April	26.45	9.81	0.83	72.87	21.59
	May	20.53	7.74	0.75	66	21.34
	June	18.12	6.11	0.87	79.98	17.64
	July	12.61	6.12	0.56	22.4	8.64
	August	16.33	6.54	0.48	28.03	8.59
	September	15.45	6.19	0.63	26.4	8.29
	October	14.16	7.12	0.59	30.86	16.11
	November	5.75	7.92	0.88	16.42	8.44
	December	46.55	4.95	0.74	70.16	7.93
2023	January	43.25	6.23	0.85	70.89	4.34
	February	33	7.66	0.65	56.68	10.24
	March	35.24	6.91	0.78	62.7	14.65
	April	26.2	5.07	0.64	44.45	16.39
	May	21.24	4.86	0.88	40.45	16.66
	June	16.01	5.2	0.96	29.94	11.24
	July	12.86	4.76	0.84	26.88	4.42
	August	15.97	5	0.79	33.02	7.27
	September	11.36	4.67	0.92	23.33	7.43
	October	23.73	5.88	0.88	36.13	8.91
	November	28.17	4.91	0.86	39.52	11.16
	December	28.3	6.87	0.96	40.03	10.21

AQI – Air Quality Index
PM2.5 – Particulate matter less than 2.5 micron in size
PM10 - Particulate matter less than 10 microns in size
NO2 – Nitrogen dioxide
CO – Carbon Monoxide
SO2 – Sulphur dioxide
(mg/m3) – milligram per cubic metre
(µg/m3) – microgram per cubic metre



Urban Systems Gap Analysis for Tirunelveli

Tirunelveli is on the cusp of substantial urban development and expansion, leading to an increased demand for municipal services and infrastructure. The city's population has grown from 0.75 million in 2001 to 0.55 million in 2021. According to population projections undertaken based on the UN World Urbanization Prospects (using the Shared Socio-economic Pathways methodology), Tirunelveli's population is forecasted to be 0.67 million by 2030, 0.85 million by 2050, and 0.96 million by 2070. This will have a direct impact on the demand for urban services and infrastructure which must cope with the growing population, adding to the pressure on the city's resources.

Tirunelveli's urban systems such as water supply, wastewater management, stormwater management, SWM, transport, and urban greening and biodiversity, as well as disaster management and emergency services, are already under considerable stress. These systems will face increased infrastructure demands, further exacerbated by the impacts of climate change. The following sections detail the existing scenario and gaps in the urban systems of Tirunelveli.

4.1 Water Supply

The engineering department of TCMC plays a crucial role in supplying water to the residents of Tirunelveli city through its water supply and distribution network. This department collaborates closely with other TCMC departments as well as external government agencies like the Tamil Nadu Public Works Department (TNPWD) and Tamil Nadu Water and Drainage Board (TWAD) to ensure the maintenance of the city's water supply infrastructure and its future expansion.

4.1.1 Water Supply Resources

The Thamirabarani River, flowing through Tirunelveli for approximately 17 km, serves as the city's lifeline and primary source of drinking water. Over the years, TCMC has collaborated with TWAD to implement 12 water supply schemes between 1955 and 2005. These schemes include various headworks and pumping stations situated along the Thamirabarani riverbed, stretching from Kondanagaram (upstream of TCMC) to Thirumalai Kolundupuram (downstream of TCMC). Among these, the Kurukkuthurai headwork, centrally located in Tirunelveli, utilises surface water drawn from the run of the river and treats it using slow sand filters. The other 11 headworks extract subsurface water through infiltration wells; this water is not treated before supply. Refer Table 4.1 for more information on the current water sourcing points in the Thamirabarani River for TCMC. The cumulative designed capacity of the headworks is 78.57 MLD, allowing Tirunelveli city to draw approximately 55.76 MLD water. Currently, the city supplies around 48 MLD, factoring in treatment losses of about 5% and transmission losses of 10%. To address the current gap and future water demands, TCMC is implementing the Tirunelveli Water Supply Improvement Scheme (WSIS) which can augment the city's water supply up to 50 MLD by drawing surface water from Ariyanayagipuram check dam, upstream of Tirunelveli city, and treating it at a new 50 MLD Water Treatment Plant (WTP). Commissioned in May 2023 and currently in the trial run phase, the project has been supplying approximately 25 MLD of water.

TCMC manages about 12 lakes in the city spanning 1.53 sq km, with a capacity of around 2.45 Million Cubic Metres (MCM), while TNPWD manages around 15 lakes with a cumulative capacity of 2.57 MCM (refer Annexure 4.1). Larger lakes like Nainarkulam and Kandiyaperi maintained by the TNPWD are purposed for irrigation but also serve as groundwater recharge points and flood buffers during the monsoon season. However, accumulation of silt in the lakes over extended periods and encroachment on the watershed areas of the inlet and outlet canals, necessitate significant rejuvenation efforts to enhance their ecosystem services[1].

Water resource assessment of the city area[2] revealed that desilting of the lakes in the city, to increase the average depth of the lakes by 20%, will increase the total capacity to 2.94 MCM in 12 TCMC-managed lakes and to 3.08 MCM in the 15 TNPWD-managed lakes, aiding water conservation and flood mitigation.

4.1.2 Water Supply & Distribution

Water sourced from the 12 headworks along the Thamirabarani River is stored and supplied to the municipal corporation area at a rate of 100 litres per capita per day (LPCD) for both metered and unmetered connections. The salient features of the TCMC's existing water supply and distribution network are presented in Table 4.2. Figure 4.1 shows the network of over-head tanks (OHTs) in Tirunelveli for distribution of municipal water to its residents.

[1] Watershed Assessment of Tirunelveli City under CapaCITIES Phase II project

[2] Assessment of water resources in Tirunelveli undertaken under the watershed assessment study of Tirunelveli city under CapaCITIES Phase II project

Table 4.1: Existing water supply sources of Tirunelveli City Municipal Corporation (2022-23)

Name of the Scheme	Year of commencement	Design quantity (MLD)	Present supply (MLD)
Manappadai Veedu (Old)	1956	8.96	4.37
Kurukkuthurai	1961	5.00	4.20
Manappadai Veedu (New)	1978	13.65	6.30
Kondanagaram (TVL)	1983	12.10	11.57
Theepatchiamman Koil	1986	1.60	0.75
Karuppanthurai	1987	0.40	0.40
Kondanagaram (MPM)	1992	7.00	5.34
Suthamalli (Old)	2000	1.60	1.21
Thirumalaikolundupuram (Old)	2001	7.00	2.75
Thirumalaikolundupuram (New)	2006	3.00	1.74
Suthamalli (New & Package I)	2007 & 2013	7.59	7.59
Suthamalli (Package II)	2013	10.67	10.67
	Total	78.57	55.76

Table 4.2: Salient features of Tirunelveli's water supply and distribution network (2022-23)[3]

Detail	Nos
Head Works	12
Booster Stations	12
Water Supply Over-head Tanks	72
Ground Level Reservoirs	17
Pumping main length (km)	145.34

[3] Source: Tirunelveli City Municipal Corporation

Detail	Nos
Distribution main length (km)	940.31
Metered Water Connections	83,259
Domestic Water Connections	76,934
Commercial Water Connections	6,254
Industrial Water Connections	71
Public Fountains	1,754
Hand Pumps	1,632
Motor Pumps (Mini OHT)	274

In 2022-23, Tirunelveli supplied water at 48 MLD, equivalent to 100 LPCD with a 3-hour daily supply duration. Municipal water is supplied daily to 40 wards, and on alternate days to 15 wards. The city's water demand based on a projected population of 554,522 in 2021, was 74.86 MLD based on 135 LPCD. With a supply of 48 MLD, there's a shortfall of about 26 MLD. Currently, Tirunelveli relies on groundwater sourced from private tankers and borewells to bridge this gap.

In addition to the water sourced from the Thamirabarani River, water is also supplied from municipal corporation owned deep borewells, supported by 274 small OHTs and water pumps. In the older parts of the town, 1,632 hand pumps help meet the demand, especially during lean piped water supply periods. Areas not covered by the water supply network receive water via tanker lorries. Given the limited municipal supply, both households and businesses rely heavily on groundwater.

It is estimated that about 30% of water consumption in the city is met through private groundwater extraction.

In summary, the city's water supply is estimated to be 68.58 MLD in 2022-23, sourced both from the Thamirabarani River and from groundwater.

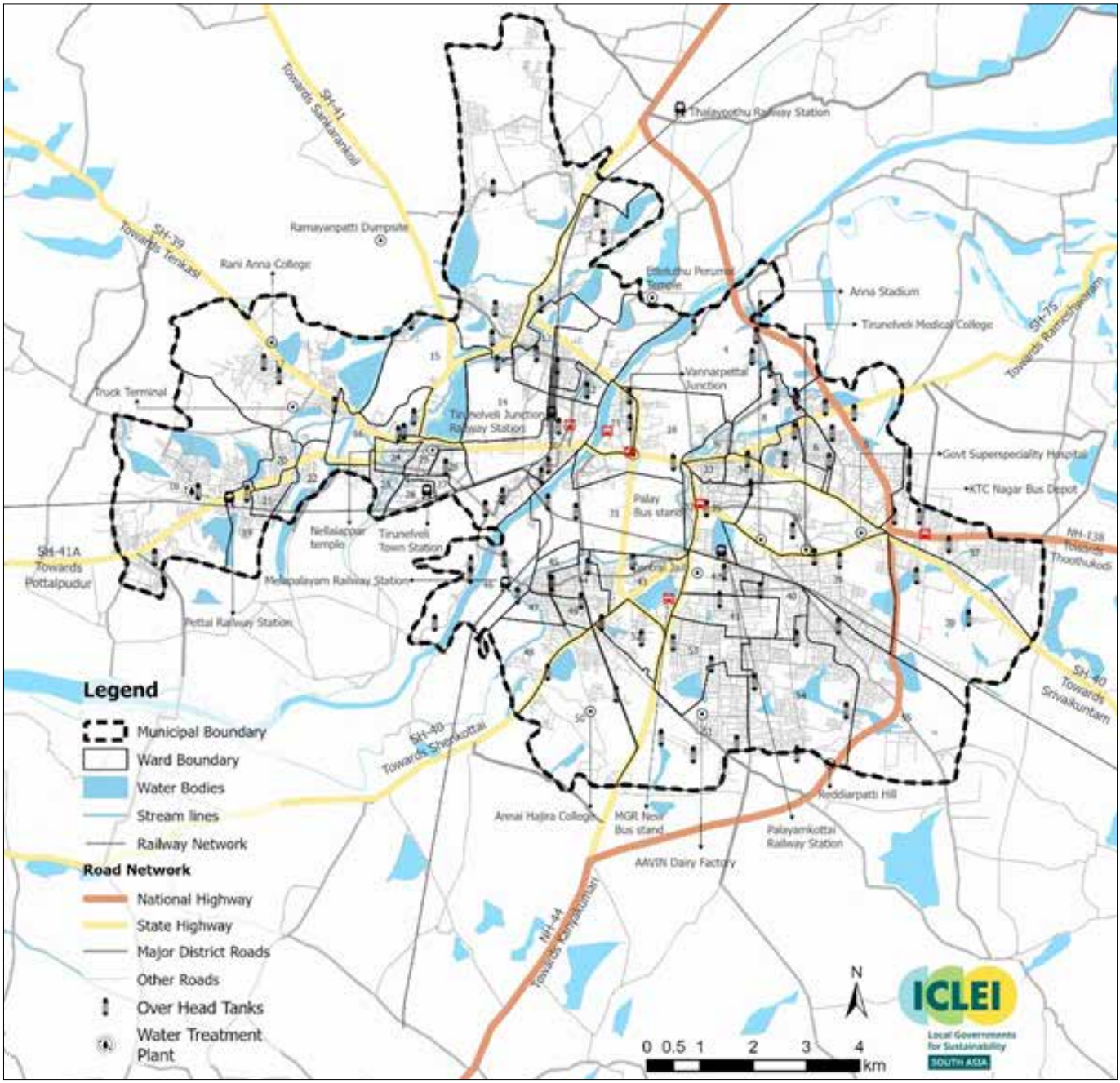


Figure 4.1: Tirunelveli's water distribution network (OHTs and WTP)[4]
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

[4] Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

Table 4.3: Service level benchmark – Municipal water supply (2022-23)

Particulars	2022-23	Benchmark	Unit
Coverage of water supply connections	95	100	%
Per capita supply of water	100	135	LPCD
Existing total public water supply (municipal water supply + municipal groundwater extraction)	48	-	MLD
Existing water treatment plant capacity	0	-	MLD
Extent of metering of water connections	54.66	100	%
Extent of non-revenue water	25	20	%
Continuity of water supply	3	24	Hrs
Efficiency in redressal of customer complaints	81.82%	80	%
Quality of water supplied	100	100	%
Cost recovery in water supply services	72.06	100	%
Efficiency in collection of water supply related charges	38.54	90	%

Source: TCMC data on DCB, Grievances and Income-Expenditure statement, 2022-23.

4.1.3 Water Supply Projects

Tirunelveli WSIS scheme for implementation of 50 MLD capacity headworks upstream of Ariyanayagipuram check dam and 50 MLD WTP at Pettai, Tirunelveli, is implemented at a cost of about INR 2,950 million. The scheme is funded by the KfW Development Bank through Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL) and is implemented in collaboration with the TWAD. To augment the water supply in Palayamkottai zone, TCMC is envisaging a 10 MLD Water Supply Scheme at Murappanadu, which will be funded through a tied grant from the 15th Finance Commission (15th FC).

4.1.4 Water Supply Issues and Challenges

Inadequate water supply: While the city relies solely on the Thamirabarani River, piped water supply is insufficient, and is often supplemented by groundwater. Access to the water supply network is limited in wards with undeveloped areas and sparse population, increasing reliance on water tanker lorries. The duration of water supply is limited to 3 hours per day, which decreases further during summer months when daily supply of water is also often interrupted. This inadequacy exacerbates the impact of climate hazards, such as urban heat, on vulnerable populations in informal settlements.

Lack of Water Treatment Plants: Tirunelveli majorly draws sub-surface water from Thamirabarani River to meet its water demand. The water undergoes only chlorination before being supplied to the residents. No dedicated WTP has been implemented to improve quality of water supply; often the municipal water supplied requires another round of purification at household level to make it potable and safer for long-term usage.

Groundwater depletion: Groundwater depletion poses a critical challenge as a considerable portion of the city's water demand is met through unregulated

[5] Service level information for water supply published by the city differs significantly from the values calculated based on primary data.

[6] Water supplied from Ariyanayagipuram WSIS 50 MLD project is not considered as the project was commissioned in May 2023 and is beyond the scope of this SLB assessment with 2022-23 as baseline year.

[7] Interest on loans for water supply infrastructure development not considered as part of WS expenditure

extraction via hand bore wells, tube wells, and private suppliers. This unsustainable practice strains the already stressed groundwater resources, particularly evident during pre-monsoon months when water tables plummet, exacerbating water scarcity in areas with irregular municipal supply.

Non-Revenue Water and Cost Recovery: Non-Revenue Water (NRW) accounts for a reported 25% of total supply. However, further assessments are required to ascertain the extent of NRW. Further, improving collection efficiency of water charges, currently at 38.54%, is imperative for enhancing the revenue stream, which is essential for future network upgrades and expansion.

Sewerage System (UGSS) projects intermittently since 1989, when a UGSS project covering Tirunelveli town and Tirunelveli Railway Junction areas was commissioned. However, this UGSS network was defunct due to severe damage and blockages, and a new UGSS network funded by Government of India's National River Conservation Program was commissioned in 2007. This project is considered as Phase I of Tirunelveli's UGSS network development.

The Phase I UGSS network covers 10 wards fully and 22 wards partially from across the city. The sewage generated is collected and channelled through street sewers to a collection well, which is then pumped to the Sewage Treatment Plant (STP) at Ramayanpatti with the aid of 4 pumping stations located strategically

Table 4.4: Stipulated projects in water supply

Project	Status	Budget
Ariayanayagipuram 50 MLD Headworks and WTP (Tirunelveli WSIS Scheme)	Commissioned in May 2023, Trial run underway	INR 2,950 million
Murappanadu 10 MLD Water Supply Scheme	Contract awarded, work to be initiated	INR 234.3 million
24 X 7 Water Supply to Pilot Water Zones – AMRUT 2.0	Contract awarded, work to be initiated	INR 264.8 million

4.2 Wastewater Management

Wastewater management is the primary responsibility of both the engineering and public health departments of TCMC. The engineering department is responsible for developing and maintaining the sewerage network and wastewater treatment plants, in coordination with external departments. The public health department is responsible for maintaining the sewerage network.

4.2.1 Underground Sewerage System in Tirunelveli

Tirunelveli city has implemented two Underground

at Balabackya Nagar, Kurichi, Vannarpettai and Nainarkulam to cater to the 4 administrative zones of the city. Table 4.5 shows the salient features of Phase I of UGSS scheme operational in the city.

The STP, with a capacity of 24.20 MLD, employs a Waste Stabilisation Pond (WSP) system comprising manual screening, grit removal, flow division, anaerobic ponds, facultative ponds, and maturation ponds. Treated effluent is discharged into natural drains and led downstream to lakes and eventually to Thamirabarani River. Table 4.6 shows the chemical characteristics of wastewater at the inlet and outlet of STP, and Figure 4.2 shows the coverage of UGSS Phase I in Tirunelveli and the location of key infrastructure.

For UGSS coverage to remaining locations in the city,

TCMC (in collaboration with TWAD and with funding from the Asian Development Bank (ADB) via Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL)) began implementation of Phase II and III of the UGSS scheme in 2018 under an outlay of INR 9,600 million. Phase II of the scheme will enhance UGSS coverage in the city's western side, while Phase III will cover all remaining locations on the eastern side of the city.

In addition to the existing STP at Ramayanpatti, a Sequential Batch Reactor (SBR) technology based STP of 58 MLD capacity will be implemented at the same location and adjoining the existing STP to address the sewage treatment needs of the city. The older STP with outdated WSP technology will be decommissioned once the 58 MLD STP is commissioned, and the entire sewerage network is diverted to it.

Further, under the direction of the National Green Tribunal (NGT), to curb pollution of Thamirabarani River, TCMC implemented Decentralised Wastewater Treatment Systems (DEWATS) at six identified major sewage outfall points on the banks of the River, but with limited success primarily due to clogging of channels caused by accumulation of silt and solid waste

Table 4.5: Salient features of Phase I UGSS in Tirunelveli (2022-23)[8]

Features of Phase I UGSS in Tirunelveli	
Sewer Line (km)	187.27
Manholes (Nos.)	7924
Pumping Station (Nos.)	4
Pumping Main (km)	12.55
Household Service Connections (Nos.)	26,882
STP Capacity (MLD & Technology)	24.20 MLD – Waste Stabilisation Pond

Table 4.6: Sewage Characteristics at Ramayanpatti STP (2021)[9]

Description	Inlet	Outlet
Biological Oxygen Demand (BOD) (mg/lit)	360	27
Total Suspended Solids (TSS) (mg/lit)	3620	36
Faecal coliform (MPN/100 ml)	38,000	1,600

[8] Tirunelveli City Municipal Corporation

[9] TNPCB Testing of STP Parameters, July 2021. Refer Annexure 4

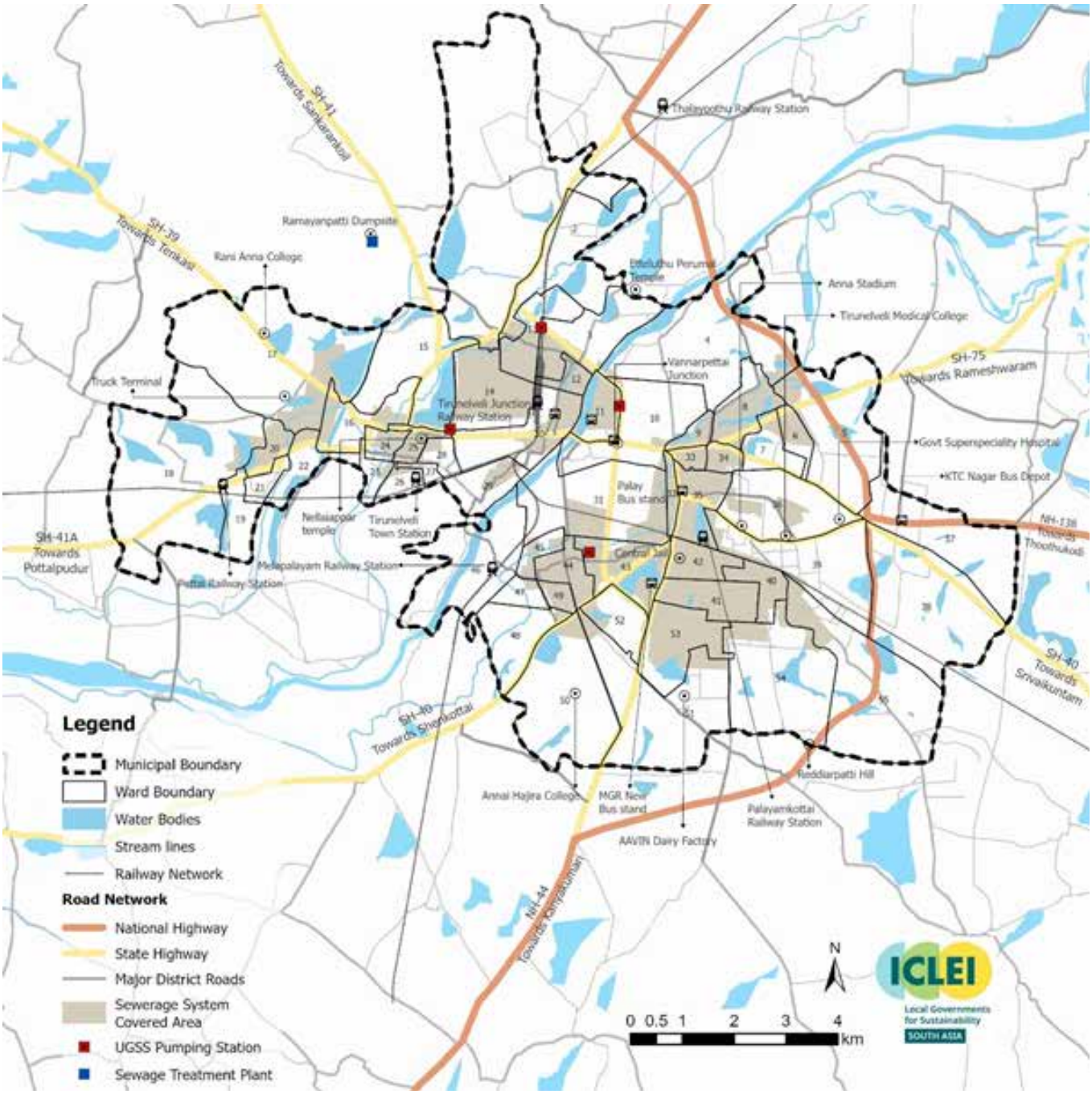


Figure 4.2: Coverage map of Phase I of UGSS scheme with pumping stations and STP locations
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

4.2.2 Wastewater Generation and Collection

The sewage generation from the city is estimated to be about 54.86 MLD in 2022-23. Due to non-functional sewers, and a smaller number of households connecting to the sewerage network, the volume that reaches the STP is only around 9 MLD against a total design capacity of 24.2 MLD. The remaining wastewater is either managed through pit latrines and septic tanks or being led directly or indirectly into Thamirabarani River.

As of 2022-23, most of the households in Tirunelveli city manage sewage through septic tanks and pit latrines. Out of the 144,662 households in the city in 2022, 35.68% use septic tanks while 18.58% are connected

to the UGSS network. The remaining households either use pit latrines or have access to community toilets for their sanitation needs.

Due to the limited coverage of the underground sewerage system in the city, the wastewater from unserved areas, especially closer to the banks of Thamirabarani River, is discharged directly into the River through the open drains at six major sewage outfall points within the city, thereby polluting the lifeline of the city. Refer Annexure 4.2 for sewage outfall points in the city and the water pollution levels in Thamirabarani River, both upstream and downstream of Tirunelveli city.

4.2.3 Wastewater Management Projects

TCMC is executing Phase II (for western side of city) and Phase III (for eastern side of city) of UGSS scheme to cover all remaining locations of Tirunelveli with UGSS network. A new STP of 58 MLD capacity with SBR technology, designed to meet the wastewater treatment needs and conform with TNPCB STP effluent norms, will also be implemented at the Ramayanpatti STP site under AMRUT 2.0 program.

4.2.4 Wastewater Management Issues and Challenges

Low UGSS coverage and under-utilisation of STP: The existing UGSS in the city serves only 18.58% of the households, with service connections provided to only 26,882 properties. Further, the Ramayanpatti STP designed for a maximum capacity of 24.2 MLD a is significantly under-utilised, processing only about 9 MLD of wastewater. This indicates a substantial underutilisation of the available treatment infrastructure.

Pollution of Thamirabarani River: Along the banks of Thamirabarani River, open drains carrying raw sewage discharge directly into the River, severely impacting the quality of water in the River, downstream of the city. Sewage discharged directly into lakes and canals ultimately pollutes the river, further reducing its natural rejuvenation capacity.

Performance of DEWATS systems: DEWATS systems, established for treating wastewater from unserved areas discharged into the rivers through known sewage outfall points have become non-functional due to siltation and solid waste clogging, leading to contamination of water bodies and the River. The systems are also overwhelmed by high quantity of sewage inflow during rainfall due to mixing of stormwater into the open drains carrying the sewage to the River.

Raw sewage in open drains: In Tirunelveli, especially in the older parts of the city, open drains also convey wastewater due to the absence of a functional underground sewerage system and/or an efficient septage management system. Open sewer drains are breeding grounds for mosquitos and other disease-causing vectors, thereby posing a significant health risk. Open drains are also frequently blocked by littered debris, thereby leading to localised stagnation and flooding, especially during periods of intense rainfall.

Table 4.7: Service level benchmark – Wastewater management (2022-23)

Particulars	2022-23	Benchmark	Unit
Coverage of toilets	95	100	%
Coverage of sewerage network services	18.58	100	%
Collection efficiency of sewerage network	16.41	100	%
Adequacy of sewage treatment capacity	44.11	100	%
Extent of reuse and recycling of sewage[10]	0	20	%
Extent of cost recovery in sewage management	21.92	100	%
Efficiency in redressal of customer complaints	56.23	80	%
Efficiency in collection of sewage charges	22.22	90	%

Table 4.8: Stipulated projects for wastewater management[11]

Project	Status	Budget
UGSS Phase II	On-going, >80% progress	INR 9,600 million
UGSS Phase III	On-going, >20% progress	
58 MLD STP with SBR Technology – AMRUT 2.0	Tendered, Work to be initiated	INR 919 million

Source: Tirunelveli City Municipal Corporation

[10] The city has not implemented earlier plans to provide treated wastewater to industries in Nanguneri and Gangaikondan SEZ.

[11] Source: Tirunelveli City Municipal Corporation

Lack of reuse of treated wastewater: The city does not have a reuse policy for treated wastewater and is yet to implement tertiary wastewater treatment plants that can enable widespread reuse of the treated wastewater, thereby limiting the potential for reuse.

4.3 Stormwater Management

Tirunelveli's stormwater management system hinges on the Thamirabarani River as the contours of the citynaturally direct the stormwater runoff towards the River that passes through the city, from both the western and eastern sides. Kodagan, Tirunelveli and Palayam canals, the three major canals built during the British era for irrigation purposes, pass through the city, along with a network of smaller irrigation canals connecting the lakes and their watershed areas, which drain into the Thamirabarani River.

These canals support the city in stormwater management, especially during north-east monsoon, when heavy rainfall is usually witnessed and act as flood buffers during flooding in the River. Figure 4.3 shows the Thamirabarani River and the three main canals that pass through the city and act as a natural stormwater drainage system for the city.

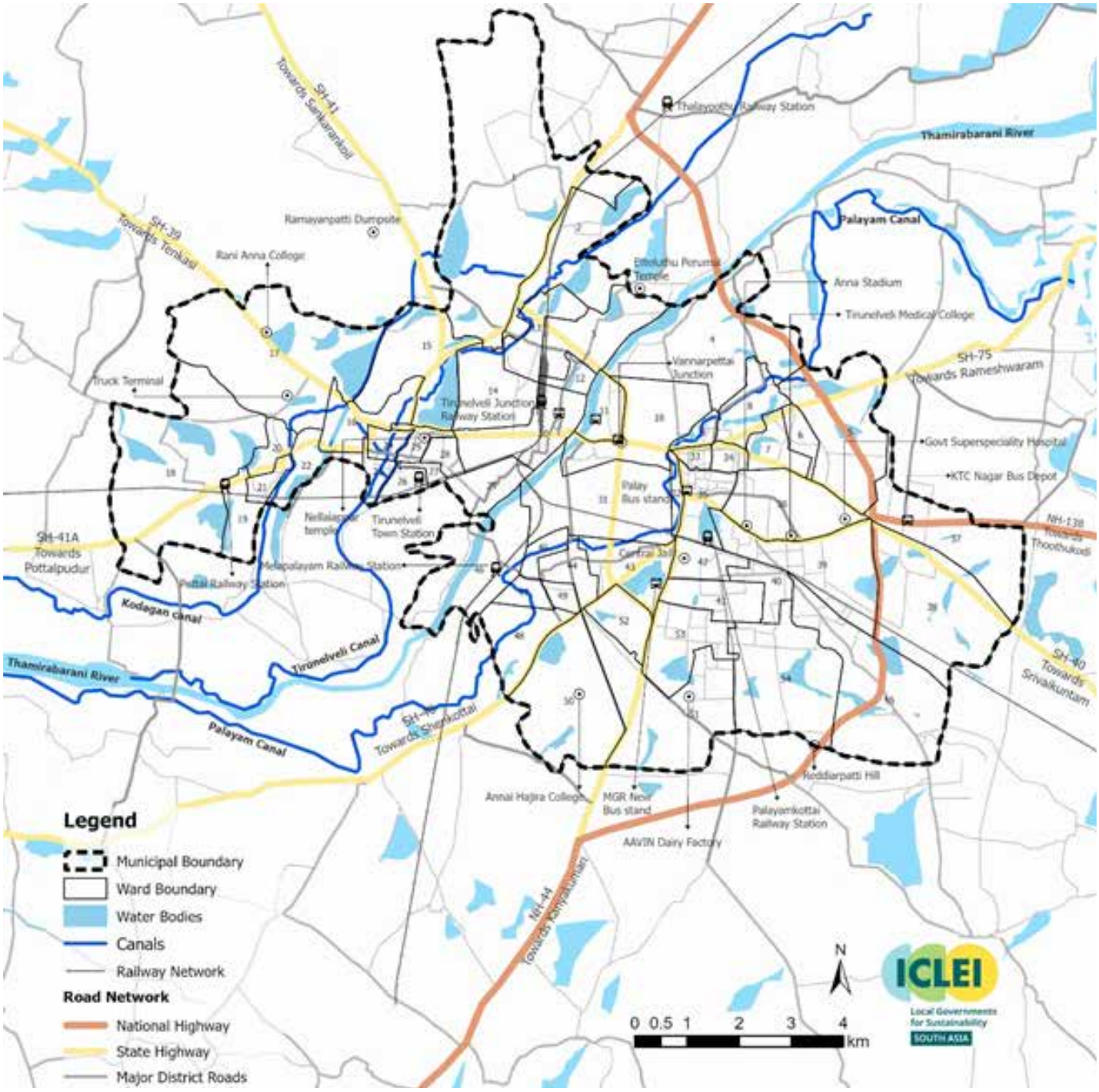


Figure 4.3: Thamirabarani River and main canals of Tirunelveli
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

Historically, Tirunelveli has been developing open unlined (kuccha) drains for stormwater management. Accumulation of silt, and encroachment of the drains by residents, have resulted in overflow, stagnation, and flooding issues. Therefore, in recent years, covered and open pucca drains are being constructed using Reinforced Cement Concrete (RCC) to reduce maintenance needs and increase the life of the stormwater drains.

4.3.1 Stormwater Drainage Network

The stormwater drainage (SWD) network in Tirunelveli extends over 269.68 km, which amounts to about 28% of the total road network of 942.48 km. Table 4.9 presents details of the SWD network in the city.

Table 4.9: SWD network in Tirunelveli

SWD Network	Length (km)
Total Network	269.68
Pucca SWD	42.90
Covered SWD	16.19
Uncovered SWD	26.71
Kuccha Drain	226.78
Culverts	1094

Source: Road Ledger (Dec 2023) and Salient Features Document (May 2023) of TCMC

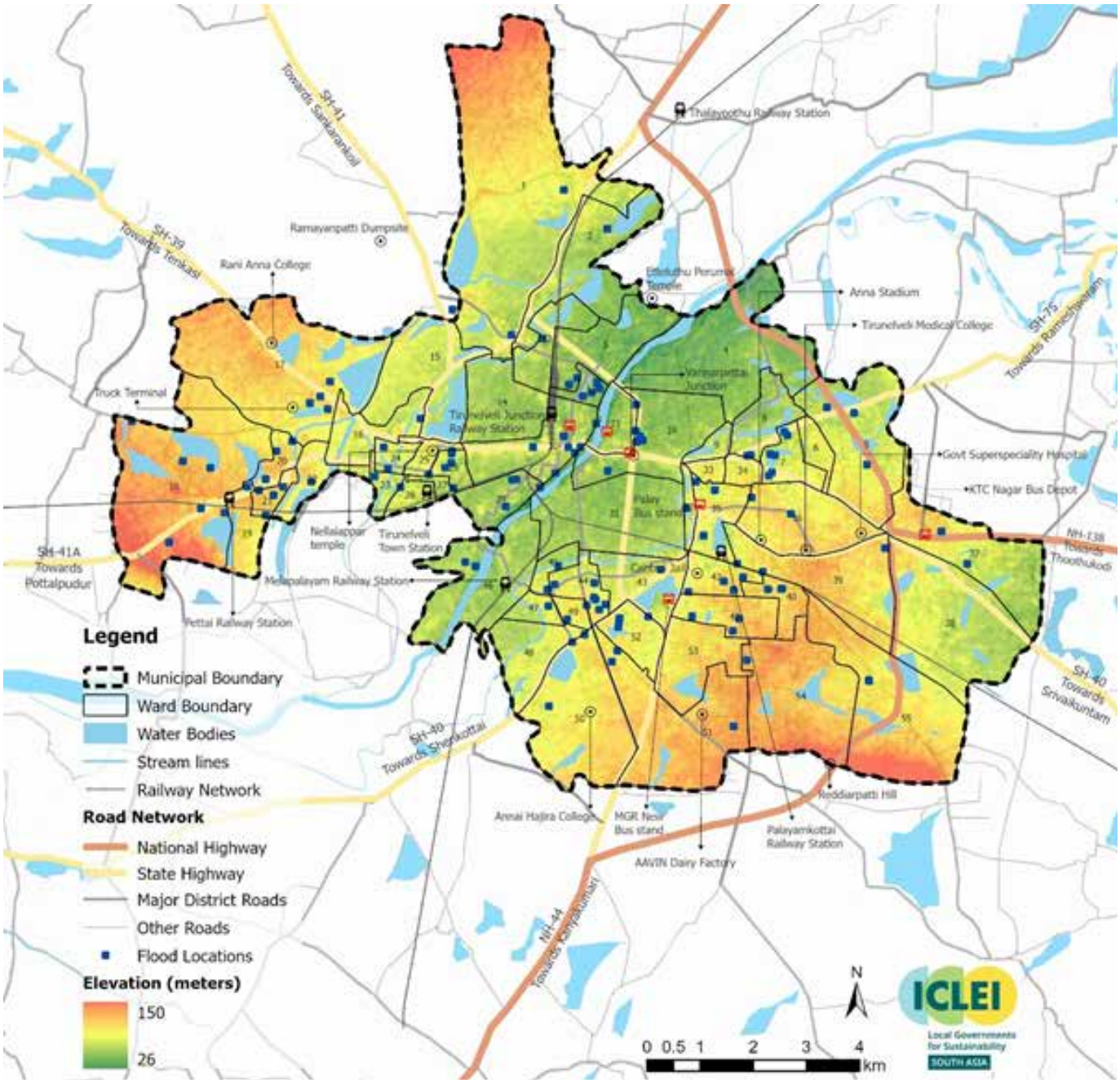


Figure 4.4: Locations vulnerable to flooding in Tirunelveli (2022-23)

4.3.2 Locations Vulnerable to Flooding in Tirunelveli

Locations vulnerable to localised flooding/stagnation in Tirunelveli were identified through field visits, an analysis of historic data available with TCMC engineers and based on the extensive flooding experienced in 2021 and more recently in 2023. Around 119 locations, including low-lying areas prone to riverine flooding, were identified as flood vulnerable locations in Tirunelveli (Figure 4.4).

4.3.3 Stormwater Management Projects

To mitigate the impacts of urban flooding in densely populated areas, TCMC is continuously expanding the extent of lined stormwater drains (pucca) drains in the uncovered areas and revamping old and existing stormwater drains. Under AMRUT 2.0, two TCMC managed lakes, which can act as flood buffers, are being rejuvenated, which includes desilting, bund strengthening, inlet and outlet channel desilting, and

Prosopis juliflora removal. Further, to improve resource allocation and disaster management during flooding in Thamirabarani River or cloudbursts in the city, TCMC is deploying a Flood Early Warning and Management System for under the CapaCITIES Phase II project.

4.3.4 Stormwater Management Issues and Challenges

Clogging of stormwater drains due to accumulation of silt and solid waste: Siltation and littering of solid waste leads to clogging of stormwater drains, significantly reducing their water conveying capacity. This key challenge necessitates targeted de-siltation efforts.

Stormwater drains doubling as sewage drains due to illegal connections: Residences without onsite septic tanks and/or soak pits discharge sewage directly into stormwater drains, causing health issues and contamination of downstream water bodies.

Low capacity of SWD network: Reduction in permeable surfaces over the years has increased surface run-off, rendering the existing SWD network inadequate to manage stormwater during periods of heavy rainfall, especially during the monsoon.

4.4 Solid Waste Management

The public health department of TCMC is responsible for the management of solid waste generated in the city. However, for developing SWM infrastructure and procuring machinery and equipment, the public health department coordinates with the engineering department.

Ten sanitary collection units, each consisting of four to six wards, headed by a Sanitary Inspector, and assisted by a Sanitary Supervisor, manage the solid waste in the city.

A sanitary collection unit is allocated the necessary equipment, manpower and vehicles for daily door-to-door waste collection and transportation to processing centres or to the landfill site at Ramayanpatti. A Zonal Sanitary Officer (SO) reporting to the City Health Officer (CHO) leads the collection units in their respective zones.

Table 4.10: Stipulated projects for stormwater management

Project	Status	Budget
SWD network in uncovered areas – Municipal Budget 2023-24	On-going	INR 155 million
Stormwater drains across wards 17, 18, 20, 24, 25, 26, 27 – Capital Grant Fund	On-going	INR 29.5 million
Rejuvenation of Gandhi Nagar Pampankulam in Tirunelveli Corporation – AMRUT 2.0	Completed	INR 19.2 million
Rejuvenation of Gandhi Nagar Pampankulam in Tirunelveli Corporation – AMRUT 2.0	On-going	INR 7.14 million
Flood Early Warning and Management System – CapaCITIES Phase II project	On-going	INR 8.83 million

Source: Tirunelveli City Municipal Corporation

4.4.1 Waste Generation & Collection

In the baseline year 2021-22, Tirunelveli city generated approximately 230 metric tonnes (MT) of municipal solid waste (MSW) daily at a per capita rate of about 415 grams. Waste characterisation details are shown in Table 4.11. TCMC has achieved around 90% efficiency in door-to-door primary waste collection. The chemical characterisation of Tirunelveli's MSW can be found in Annexure 4.3.

In 2022-23, TCMC appointed a private entity for secondary collection of waste. Around 100 secondary waste collection bins were strategically placed across the city. Segregated waste from primary collection is transferred to the micro compost centres and the residual waste is disposed in the secondary collection bins (dumpers). Compactors and dumpers transfer waste from the secondary collection bins to the Ramayanpatti dumpsite. Details of vehicles used for primary and secondary waste collection and transportation in the city can be found in Annexure 4.4.

4.4.2 Waste Recovery & Treatment

In 2016, the city implemented a 5 TPD biomethanation plant, and has over the years developed 32 decentralised Micro Compost Centres (MCCs) with capacity ranging from 0.5 TPD to 3 TPD, 14 On-site Compost Centres (OCCs) with capacity less than 0.5 TPD and a 20 TPD centralised MCC at Ramayanpatti. The city has a total installed capacity of 80 TPD to process biodegradable waste. The details of the MCCs operational in the city and mapping of their catchment area can be found in Annexure 4.5.

Although the cumulative capacity of bio-degradable waste treatment is 80 TPD, the actual waste processed is around 25 TPD (2021-22), highlighting the operational challenges and inefficiencies in segregated bio-degradable waste collection and processing. To recover and recycle dry waste from the mixed waste being disposed at the Ramayanpatti dumpsite, a 50 TPD MRF plant is proposed.

In 2021-22, approximately 205 TPD mixed waste was being mismanaged, with 100 TPD being dumped at the Ramayanpatti dumpsite. Notably, Tirunelveli has no dedicated policy or infrastructure for management of Construction & Demolition (C&D) waste and electronic waste; this waste is managed entirely by the informal sector.

Table 4.11: Physical characterisation of municipal solid waste (2022)

MSW Type	Composition (%)	MSW Type	Composition (%)
Food waste	44.18	Rubber	0.34
Garden and Park	19.59	Industrial	0.00
Paper/cardboard	7.14	Plastics	7.45
Wood and Straw	8.45	Glass	0.38
Textiles	1.51	Steel	0.43
Disposable nappies	2.08	Inert	8.45

Source: MSW Characterisation study undertaken under CapaCITIES Phase II project in 2022

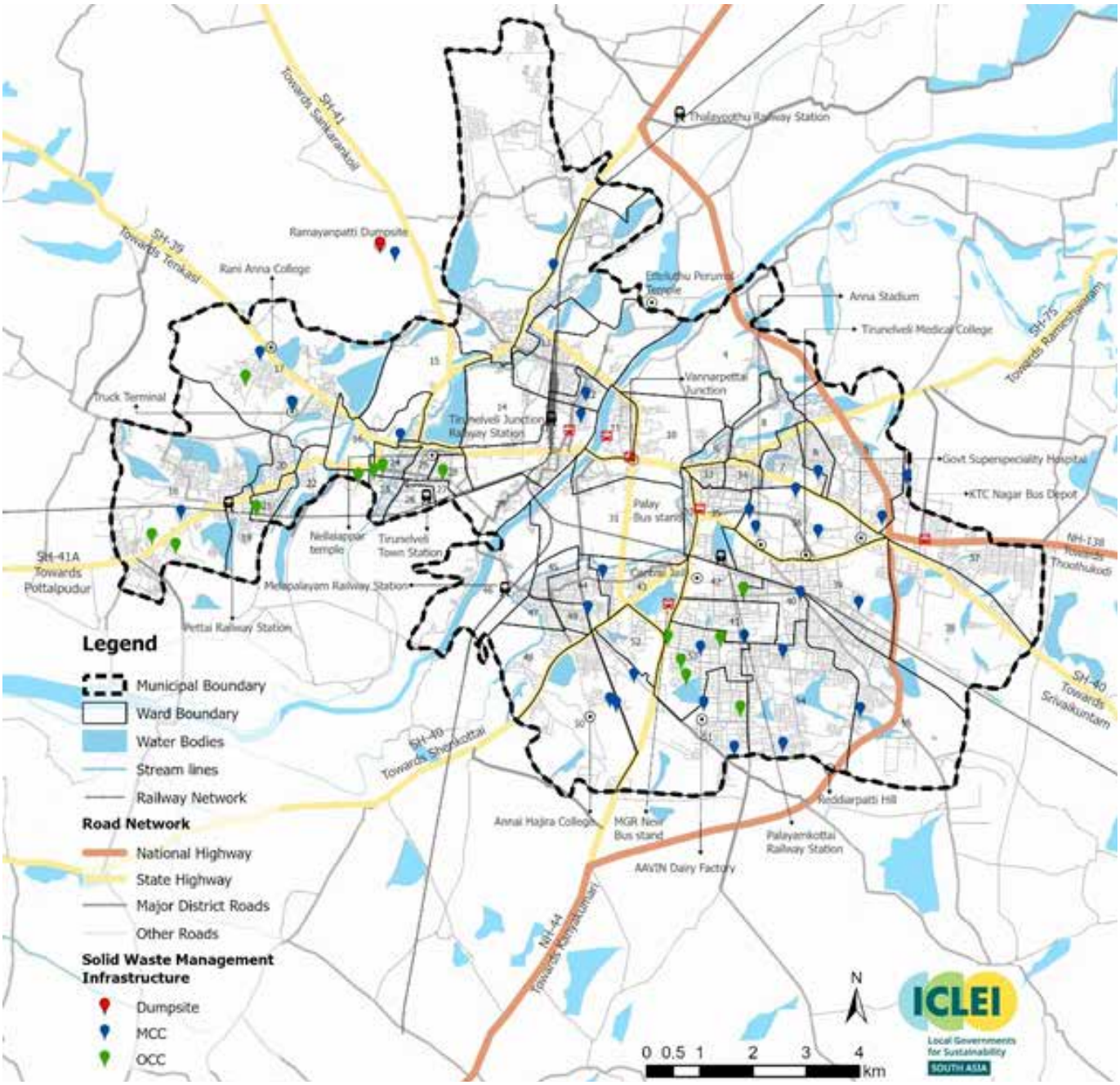


Figure 4.5: Solid waste treatment facilities and disposal site
Source: Prepared by ICLEI South Asia

Table 4.12: Service level benchmark - Solid waste management (2022-23)

Particulars	2022-23	Benchmark	Unit
Total waste generation	230	-	TPD
Household level coverage of SWM services	100	100	%
Efficiency of collection of municipal solid waste (MSW)	90	100	%
Extent of segregation of MSW	40	100	%
Extent of solid waste recovered	10	80	%
Extent of scientific disposal of MSW	0	100	%
Extent of cost recovery in SWM services	NA	100	%
Efficiency in redressal of customer complaints	69.65	80	%
Efficiency in collection of SWM charges	56.52	90	%

TCMC data on DCB, Grievances and Income-Expenditure statement, 2022-23.

4.4.3 Solid Waste Management Projects

TCMC is keen to develop waste processing and treatment facilities at the Ramayanpatti dumpsite. Table 4.13 presents the projects proposed to manage the mixed waste reaching the dumpsite.

4.4.4 SWM Issues and Challenges

Open dumping of solid waste: Solid waste can often be seen dumped along roads and dumpsters overflowing, due to inadequate primary collection.

Limited segregation of waste at source: Segregation of waste at source is limited due to lack of awareness among citizens. Mixed waste is often directly transferred to secondary waste collection points without any processing.

Absence of decentralised material recovery facilities and transfer stations: The mixed waste collected is directly transferred to secondary waste collection points and eventually to the dumpsite without segregation/compaction or processing at a transfer station or decentralised material recovery facility (MRF). Therefore, high quantities of mixed waste reaching the disposal site overwhelms the processing and treatment facilities located at the Ramayanpatti dumpsite.

Table 4.13: Stipulated projects for solid waste management

Project	Status	Budget
100 TPD Pre-processing Plant and Windrow Composting Platform	DPR prepared, awaiting sanctions	INR 43 million
Bio CNG Project	DPR prepared	NA
Rendering Plant at Ramayanpatti Dumpsite – Private	On-going	NA

Source: Tirunelveli City Municipal Corporation

[12] Assumed based on field surveys during Waste Quantification and Characterisation Survey

[13] Assumed based on field surveys during Waste Quantification and Characterisation Survey

Underutilisation of micro-compost centres: Due to lack of source segregation of waste, only small quantities of bio-degradable waste are processed at the decentralised micro-composting facilities.

Cost recovery: The collection efficiency of SWM charges is 56.52% which undermines the city's capacity to manage solid waste. Strict regulations and improving the convenience of payment of charges through e-governance modes could improve efficiency of collection and cost recovery.

4.5 Transportation

Tirunelveli is a small city with less than a million population and mixed land use, catering mainly to residential and institutional purposes. The city has high density development in 4 distinct urban centres which are interconnected through arterial roads including SHs. Traffic congestion is common during peak hours and holidays or festivals, primarily due to heavy traffic flow resulting from movement between urban centres or towards key transportation hubs like the central bus terminus and railway junction. The increasing number of private vehicles are adding to the traffic congestion. With limited parking facilities, leading to haphazard roadside parking, traffic congestion and mobility challenges in the city are exacerbated.

4.5.1 Road Network

Tirunelveli city is connected via roads to different urban communities of Tamil Nadu by NH 44 and NH 138, which play a key role in intra-state transport in the state. The road network in Tirunelveli city spans about 942.48 km, most of which have flexible pavement made of bituminous (BT) surface (~98%). In contrast, cement concrete (CC) surfaces make up about 1% of rigidly paved roads. Table 4.14 shows the length of several types of road network present in the city.

In Tirunelveli city, a substantial portion of the streets and roads are narrow, especially in the older parts of the city, and often get clogged with motor vehicles, bicycles, and pedestrians during peak hours. Unplanned intersections, restricted one-way roads, including SHs passing through the city, cause traffic congestion. Conversely, the extension areas on the eastern side of the city have wider, well-laid roads facilitating smooth traffic flow.

The city is bordered by NH 44 that passes along its eastern edge. To ease traffic movement, the city is planning to develop a ring road, comprising the NH44 bypass road and the new western bypass road connecting Sankarnagar to Reddiarpatti which will be connected to the internal arterial roads. NH 138 will also be connected to one of the ring roads.[14]

4.5.2 Mobility Profile and Baseline

The year-on-year increase in vehicle registration is not as rapid as in the major cities of Tamil Nadu. Nevertheless, two-wheelers that account for 76.14% of new vehicle registrations (as recorded in year 2021), are the main contributors to Tirunelveli's growing vehicular population.

Motorcycles are the prominent mode of private transport as can be seen from their annual registration statistics; they also have the highest mode share

Table 4.14: Length of road network in Tirunelveli

Type of Road	Length (km)
Corporation Roads	807.63
National Highways	22.20
State Highways	60.13
Major District Road	30.24
Other District Roads	22.28
Total	942.48

Source: Comprehensive Mobility Plan, Tirunelveli Local Planning Area

[14] Comprehensive Mobility Plan, Tirunelveli Master Plan 2021

among all mobility options (Figure 4.6). Bicycles are commonly used for short distances, but the lack of dedicated lanes has resulted in their decreased use, compounded by safety concerns on roads shared with the increasing number of motor vehicles. Autorickshaws, efficient for navigating narrow streets, are the prominent mode of shared transport in older city areas, catering to last-mile connectivity needs. Public transport share in Tirunelveli's mobility landscape is 23%.

The average trip generation rate in Tirunelveli (including non-motorised trips) is 1.24, which amounts to 687,607 trips per day in Tirunelveli. The average trip length in the city is 7.2 km. The share of passenger trips is 85.52% and freight trips is 14.48%.[16]

Tirunelveli's uptake of Electric Vehicles (EVs) and development of both public and private EV charging infrastructure in the city is relatively slow. Therefore, almost all trips made in the city are through Internal Combustion Engine (ICE) vehicles or non-motorised transport (NMT). Notably, transport is the highest GHG emissions contributor after residential and commercial buildings in Tirunelveli; this translates to a high per capita GHG emissions for every km travelled in the city.

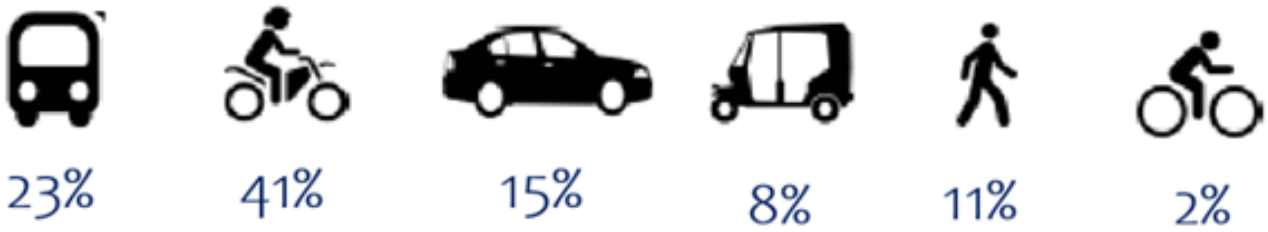


Figure 4.6: Mode Share in Tirunelveli

4.5.3 Pedestrian and Non-Motorised Transport

Based on the road network inventory study, it is evident that more than 70% of the roads in Tirunelveli have no footpath. Of the roads with dedicated footpath, only around 10% have paved sidewalks dedicated to pedestrian movement. The rest are unpaved footpaths located on the shoulder of roads.

Owing to the flat and undulating terrain of Tirunelveli, bicycles are still a popular mode for commuting short distances, especially in the older areas of the city with narrow roads and traffic congestion. A new cycle track of 4 km length has been implemented in the eastern part of the city under the Smart City Mission.

4.5.4 Intermediate Public Transport

Intermediate Public Transport (IPT) in Tirunelveli consists of 3-seater auto-rickshaws, including shared auto-rickshaws which are hired mostly for short trips due to their inflated costs in the absence of government regulation. Despite public transport having a higher mode share than IPT, safety concerns coupled with lack of route coverage up to the last mile are the key factors deterring IPT users from switching to public transport.[17]

4.5.5 Public Transport

In Tamil Nadu, public transportation is managed by the Tamil Nadu State Transport Corporation (TNSTC), a state authority that operates public transport across the state through its regional offices.

Tirunelveli city is served by a fleet strength of 299 TNSTC buses and 92 private buses (~0.7 buses/1,000 persons against the government norm of 0.6) including local, intercity, and interstate buses operating from the M.G.R New Bus Stand, Palayamkottai Bus Stand, and Tirunelveli Junction Periyar Bus Stand, catering not only to the city but also to areas in its vicinity. TNSTC manages the maintenance of Tirunelveli's public transport fleet through its 3 depots located at KTC Nagar, Vannarpettai and Kokkirakulam.

[15] Vehicle registration data, Regional Transport Office, Tirunelveli

[16] Comprehensive Mobility Plan, Tirunelveli Local Planning Area

[17] Comprehensive Mobility Plan, Tirunelveli Local Planning Area

Table 4.15: Footpaths in Tirunelveli

Footpath Width (m)	% of Road Length
Footpath (Nos)	70
Up to 1.2 m	28
1.2 to 1.8 m	2
More than 1.8 m	0

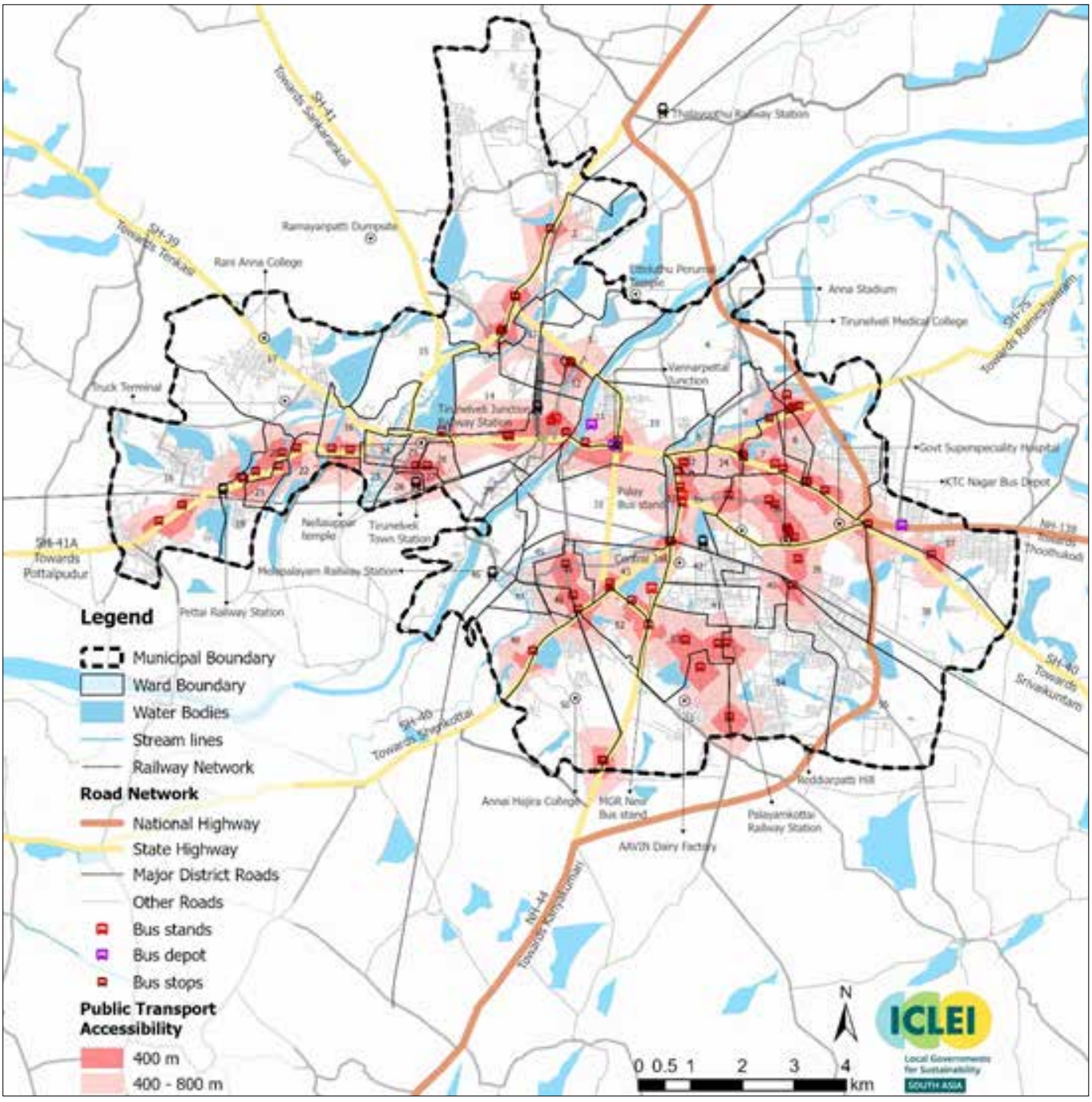


Figure 4.7: Accessibility of public transport network
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

Tirunelveli city has 90 bus stops spread across the city, particularly along the arterial roads and older roads connecting the erstwhile municipalities of Tirunelveli, Palayamkottai, Melapalayam and Thatchanallur town panchayat (Figure 4.7). Residential localities and commercial areas within 800 m walking distance from the public bus stops are found to have the best access to the public transport network of Tirunelveli.

4.5.6 Freight Transport

Freight movement in the city is not regulated strictly enough, adding to the traffic congestion woes in the city. Although a dedicated truck terminal was built under the Smart City Mission, ease of connectivity to the major road networks has prevented the truck terminal from serving its purpose of reducing the movement of heavy vehicles in the city. Light Commercial Vehicles and Goods Autos, with high modal share of 43% and 16% respectively among freight vehicles, dominate freight movement in the city. These are typically used for retail goods transfer, especially fresh produce which require daily transportation.

4.5.7 Transportation Issues and Challenges

Lack of integration of transport modes: Integration of public transport with IPT systems to enable last-mile connectivity especially in areas uncovered by public transport is lacking and impacts public transport accessibility for the citizens.

Lack of regulation of IPT operations: Inadequate quality of public transport services and city-wide route coverage has made IPT vehicles, such as auto rickshaws and shared autos, popular for short trips and last mile connectivity. Lack of regulation has led to arbitrary charging of higher fares to the public for IPT services.

Haphazard and street parking: Lack of adequate parking spaces and regularised road-side parking of vehicles is a key challenge in managing traffic, especially in the older parts of the city.

Poor infrastructure at key transport nodes: Bus stops at key traffic nodes such as Vannarpettai Junction and Arvind Eye Hospital lack adequate infrastructure to ease accessibility to public transport fleet by integrating IPT vehicles.

Poorly planned development of traffic junctions in the city: The 17 major traffic junctions in the city must be re-designed and developed considering sustainable design options and citizen inputs from inclusive participation of both pedestrians and vehicle users.

Lack of NMT Infrastructure in the city: Tirunelveli has road network totalling 942.48 km. However, availability of NMT infrastructure, and pedestrian and non-motorised vehicle movement is abysmal.

Lack of policy/plan on adoption of EVs and development of EV charging infrastructure: Absence of local policy or plan on adoption of EVs and development of the associated charging infrastructure has led to low uptake of EVs for daily use. The most commonly visible EVs are the electric scooters that can easily be charged at home. There is a significant lack of public EV charging infrastructure. Initial adoption of EVs by IPT stakeholders and for public transit that can act as model for accelerated adoption of EVs is also absent in Tirunelveli.

4.6 Urban Biodiversity

Waterbodies, agriculture, open scrublands, avenue trees, parks and gardens, institutional spaces provide habitat for biodiversity in the city of Tirunelveli. 141 species of trees, belonging to 44 families of dicotyledons and 3 families of monocotyledons have been recorded from the city. Out of these 46 species are timber yielding[18], 57 species are ornamentals, and 20 species are fruit-yielding . In another study, 133 species of avenue tree species belonging to 103 genera and 42 families have been recorded within a 10 km radius circle of the city centre of Tirunelveli.[19]

76 species of geophytes, belonging to 29 families and 58 genera have been recorded. Out of these, 44 ornamental geophytes have been seen grown in home gardens in the city. Alocasia sanderiana, a

[18] Priya P.V. et. al. (2020), An assessment of tree species diversity in Tirunelveli corporation area, Tamil Nadu, International Journal of Current Research in Life Sciences, Retrieved in May 2024.

[19] Ramarajan Sekar et. al. (2022), Checklist of tree species in urban regions of Tirunelveli, Tamil Nadu, Indian Journal of Plant Sciences, Retrieved in May 2024.

[20] Saravana Ganthi A. et.al. (2020), Checklist of geophytes in Tirunelveli corporation area, Tamil Nadu, India, Annals of Plant Sciences, Retrieved May 2024.

[21] Jeyapraba L. et. Al. (2017), A preliminary study of butterfly in Tirunelveli, Tamil Nadu, International Journal of Scientific Research and Modern Education, Retrieved May 2024.

critically endangered species and 20 species of exotic geophytes have been reported from Tirunelveli city[20].

A rapid assessment of butterflies, carried out in 2017, reported the presence of 20 species was recorded. Out of the 20 species, twelve belonged to Nymphalidae, three to Pieridae, one to Lycaenidae and four to Papilionidae families. Species belonging to the family Nymphalidae were the most dominant (60 %) followed by Papilionidae (20%), Pieridae (15 %) and Lycaenidae (5%). Among the 20 butterflies recorded 2 species Pachliopta hector and Hypolimnas misippus fall under schedule I of the Wildlife (Protection) Act[21].

There are a few protected areas present close by. This further highlights the significant role that the city plays in maintenance of the biodiversity in the region. The protected areas are:

- Kalakkad- Mundanthurai Tiger Reserve – Located

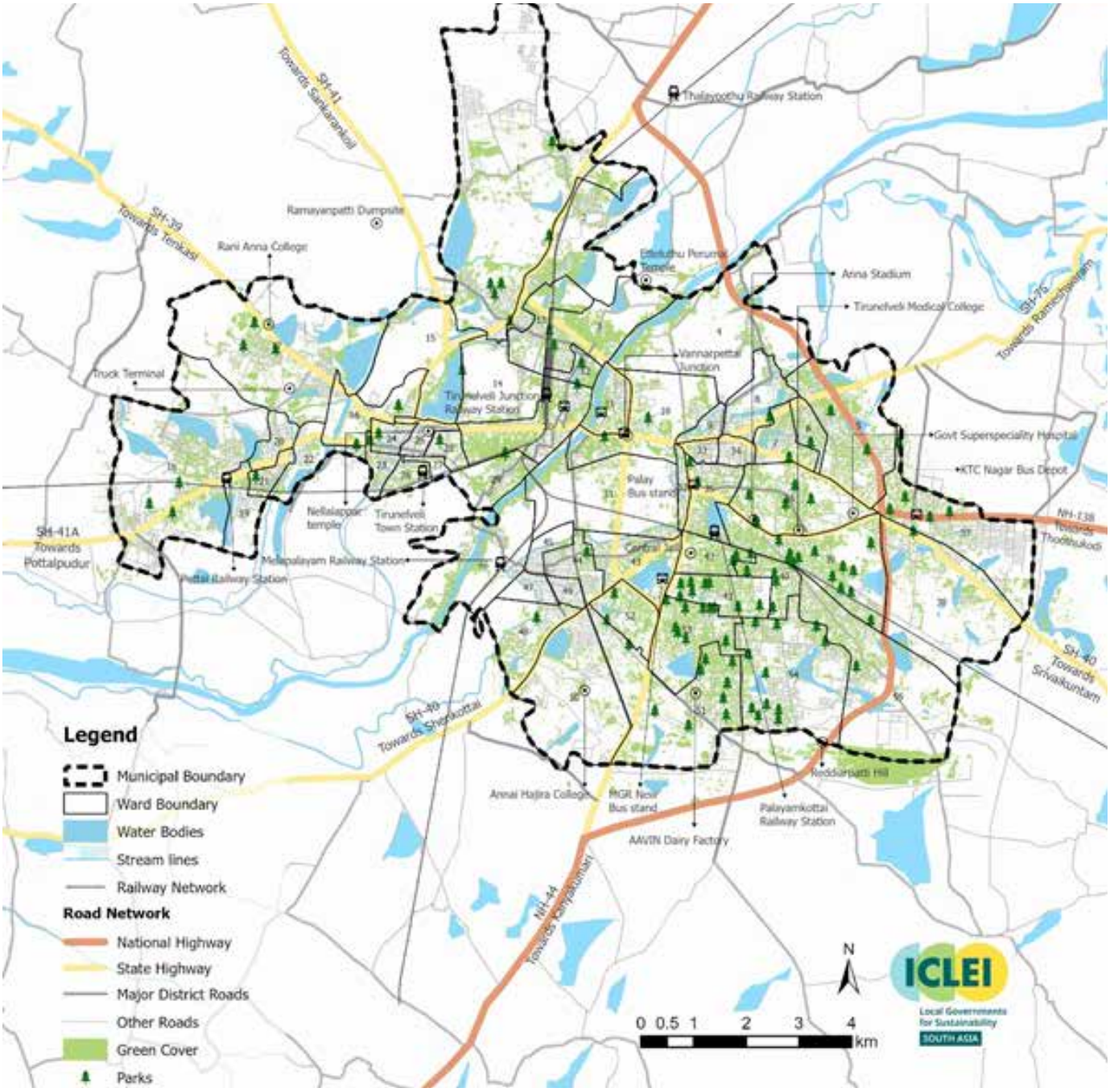


Figure 4.8: Tirunelveli green cover map
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

60 kms away from city.

- Bird Sanctuary at Koonthankulam, a Ramsar site – Located 28 kms away from city.
- Vallanadu Blackbuck Wildlife Sanctuary- Located 23 kms from city.

The key threats to the urban biodiversity in Tirunelveli city include:

- Land use change,
- Spread of invasive species like Prosopis juliflora,
- Reduced rainfall,
- Discharge of sewage and industrial effluents and dumping of solid waste into the waterbodies.

A GIS assessment of Tirunelveli was conducted to determine the extent of green cover within the city. The findings revealed that Tirunelveli has approximately 27.51 sq. km of green cover, accounting for 25.32% of the city area. TCMC has also been actively promoting development of green parks in the city and planting native trees to increase the tree cover, as well as the health of the green ecosystems in the city with tree

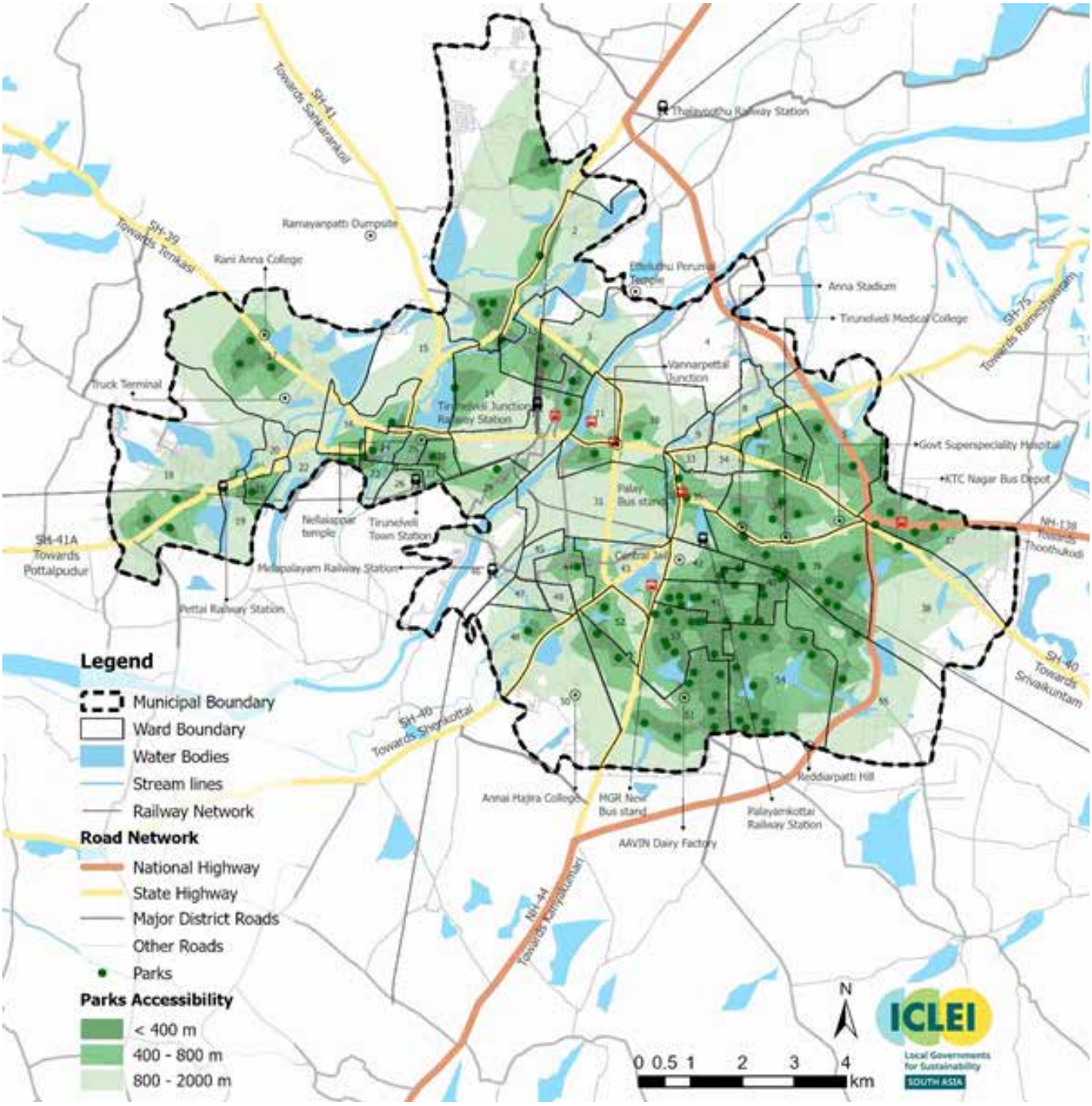


Figure 4.9: Accessibility to public parks in Tirunelveli.
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

cover from native species. The city in recent years has developed more than 90 parks with funding assistance from KfW Development Bank, AMRUT scheme and Smart City Mission. The list of developed parks in the city can be found in Annexure 4.6

From Figure 4.9, it is evident that the eastern half of the city, especially wards 35, 36, 37, 39, 40, 41, 42, 51, 53, and 54, have substantial number of developed parks owing to the land availability from significant residential and mixed-use development witnessed in these parts of the city in the last decade.

The availability of green cover in the densely developed areas of the city is very low and the residents of these are found to have poor accessibility to parks, which can impact long-term liveability of such areas in the cit

4.7 Built Environment and Energy

Tirunelveli's built-up area as per the existing land use scenario in 2021 is 56% of the total city area of 108.65 sq km. The city's built-up area can be categorised as follows:

Residential Areas: Historically, the city's development has been focused around the 4 distinct urban centres with a buzzling commercial area at its centre. However, in the recent years, areas such as Kodeeswaran Nagar, Shanthi Nagar, KTC Nagar, Perumalpuram, Thiyagaraja Nagar, and Maharaja Nagar have witnessed significant residential developments, offering a mix of independent houses and apartment complexes.

Commercial Areas: The commercial areas of Tirunelveli are traditionally centred within the 4 urban centres and along the main arterial roads of Tirunelveli, the S.N. High Road, Tiruchendur Main Road and Trivandrum Road, featuring shopping malls, markets, banks, and corporate offices.

Industrial Areas: Tirunelveli has an industrial estate developed by Small Industries Development Corporation (SIDCO) in the Pettai area located on the western side of the city.

Institutional Areas: Tirunelveli hosts several renowned educational institutions on the eastern part of the city, which is also home to regional headquarters of several government agencies and their accommodation quarters. Tirunelveli Medical College and Hospital, Government Siddha College, Government Multi-Speciality Hospital, Naval Signal Station of INS Kattabomman, Government Engineering College, and Government Law College are some of the notable government institutions located on the eastern side of the city.

Transportation: Tirunelveli's key transportation infrastructure include 942.48 km of roads, Tirunelveli Railway Junction, 3 bus stands, 3 bus depots and around 90 bus stops.

Municipal Infrastructure and Facilities: include municipal infrastructure for street lighting, water supply, stormwater, sewerage and SWM, public offices, and schools.

Emergency Facilities: include healthcare facilities, fire station, and police stations.

In 2021-22, total electricity consumption by the built environment was 503.94 million kilowatt hours (kWh) and the total energy consumption from stationary fuel was 1.6 million giga joules (GJ). Residential buildings are the prime drivers of energy consumption in Tirunelveli and contribute the most to GHG emissions from the city.

4.8 Disaster Management & Emergency Systems

Efficiency and accessibility of emergency services (fire and health infrastructure) are essential to enhance the adaptive capacity of a city to respond effectively to climate change disasters and reduce risks faced by the citizens, especially the vulnerable population. Low-income group households in slum locations, differently abled people, children, and the elderly are more vulnerable to climate change disasters. It is imperative to improve accessibility to emergency services such as hospitals and fire stations, and to urban infrastructure such as public transport stations/stops and green park spaces.

4.8.1 Accessibility to Fire Stations

Methodology Used: Spatial analysis of fire stations and accessibility within 7 km service area radius around fire stations has been considered for analysis.

Data Used: Location of fire stations

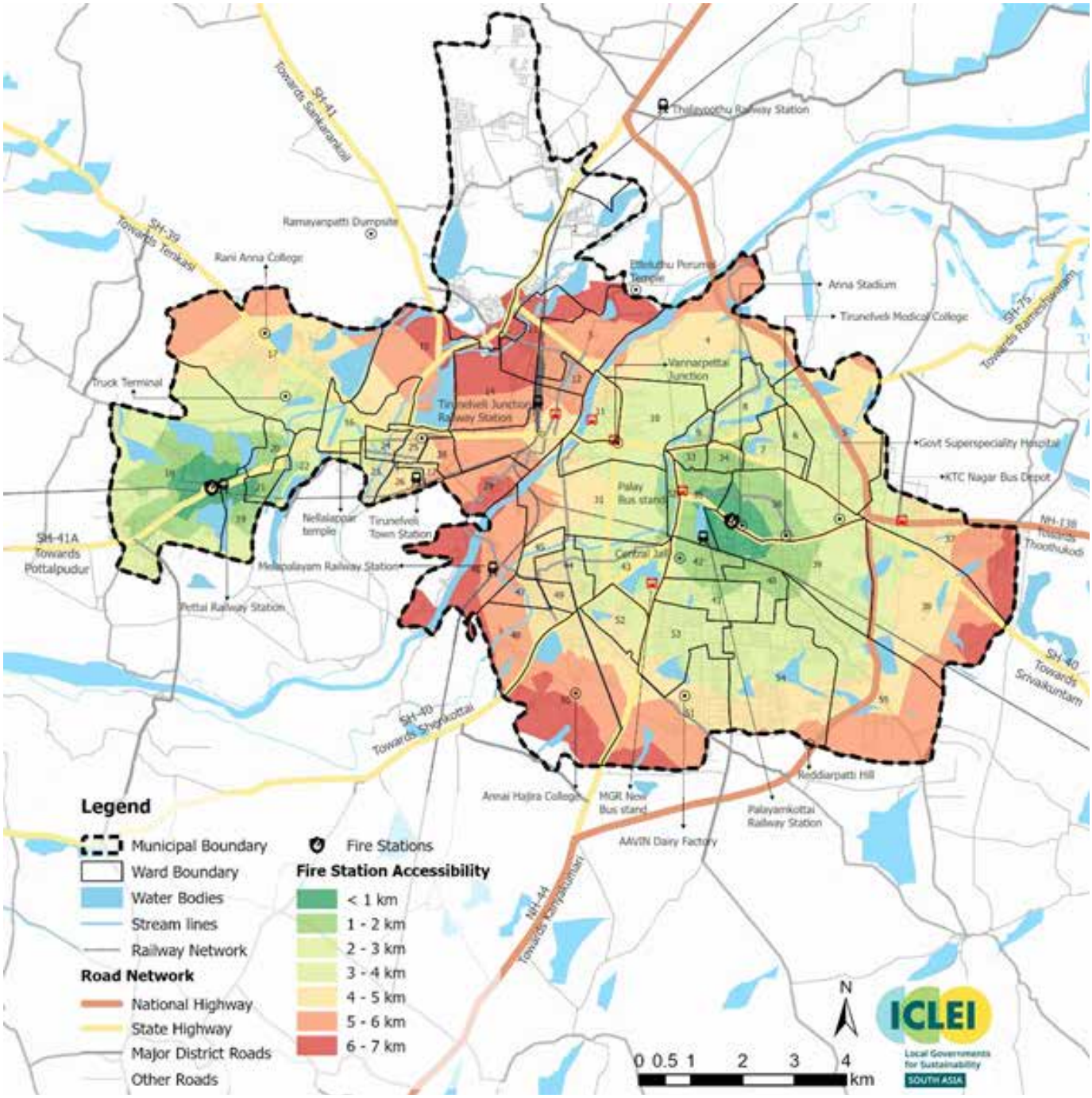


Figure 4.10: Accessibility of fire service stations in Tirunelveli
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

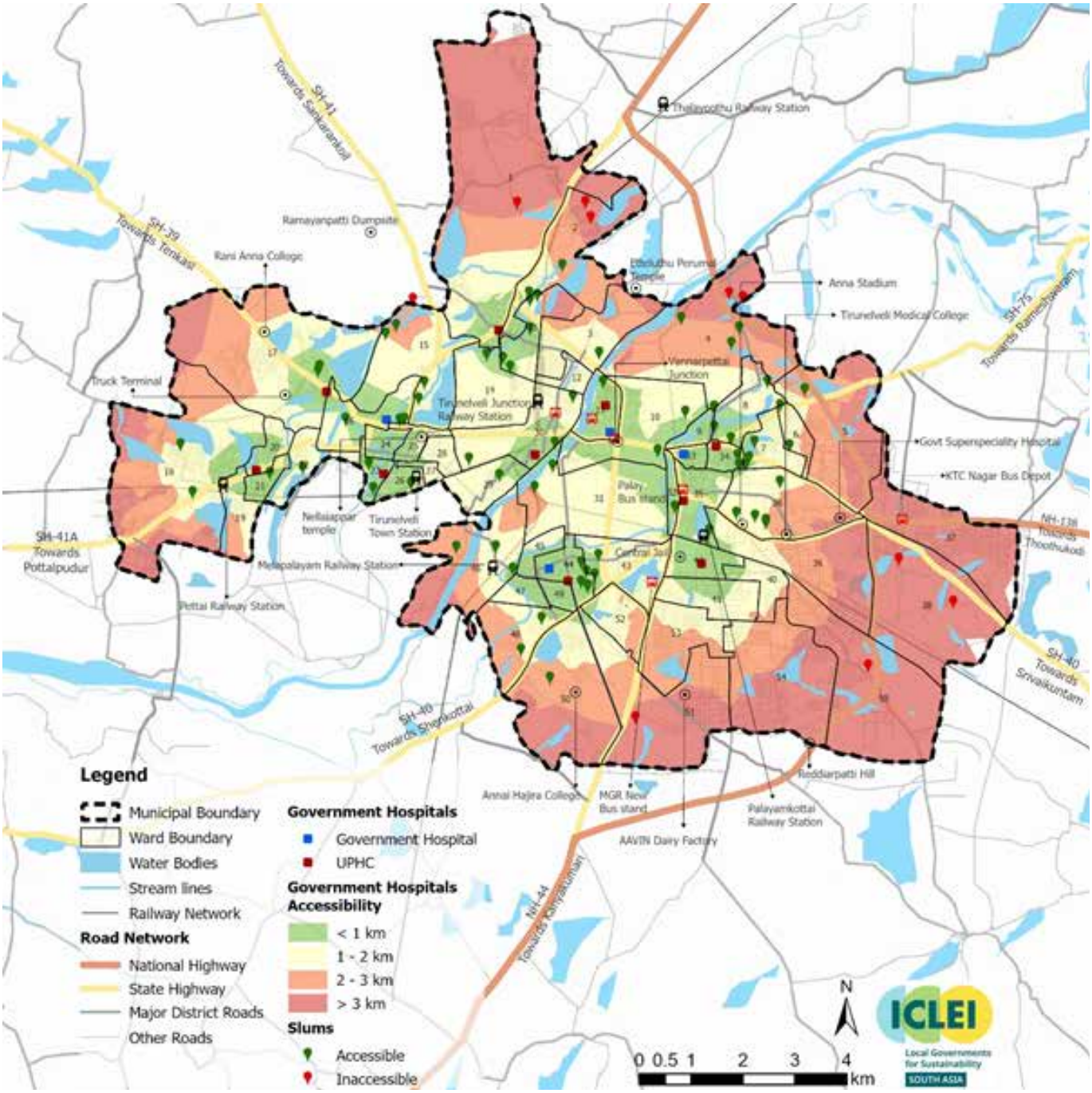


Figure 4.11: Accessibility of government health care facilities for slum dwellers

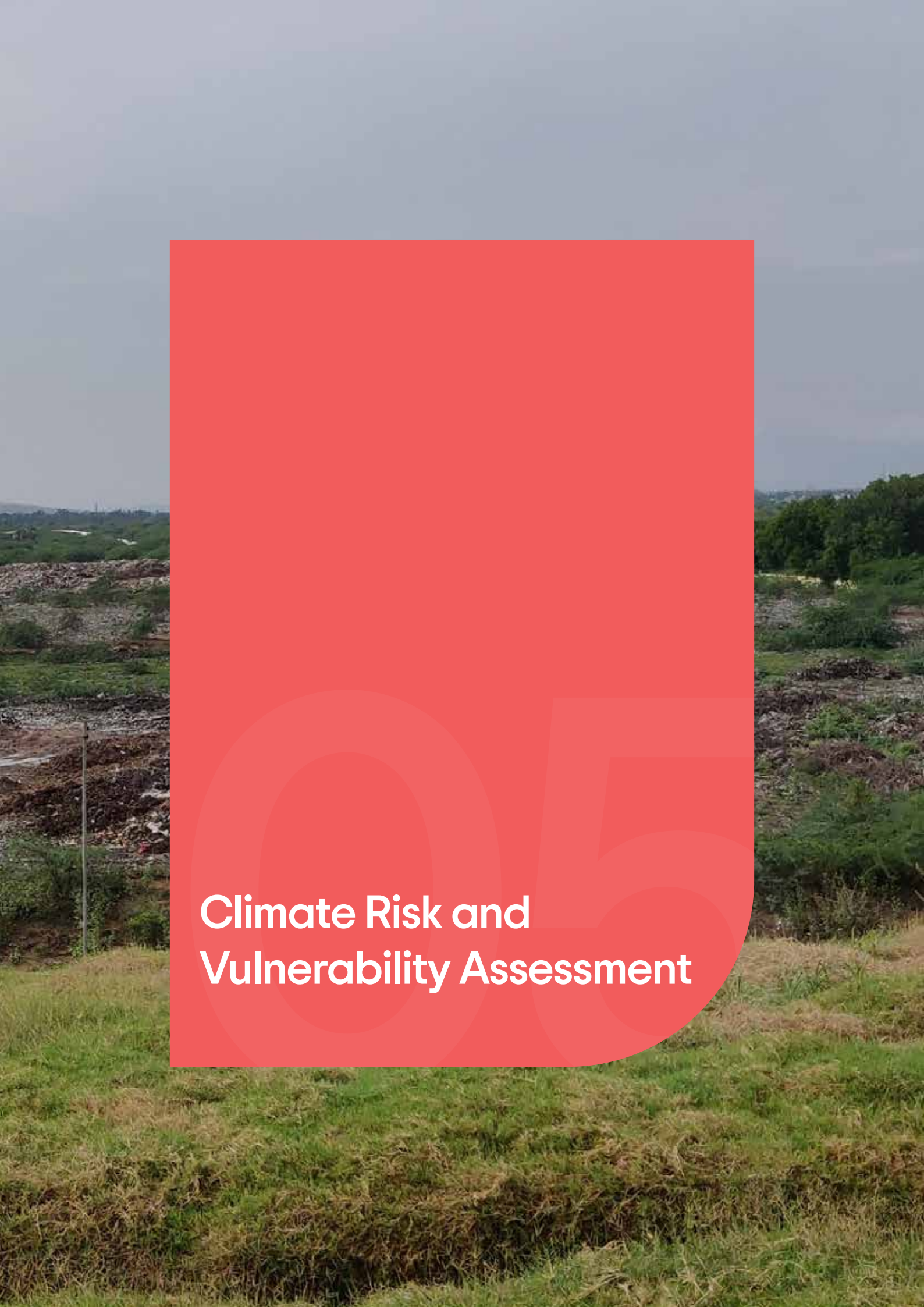
4.8.2Accessibility to Health Services

Tirunelveli city has 10 primary health centres, 6 government hospitals and 89 private hospitals with hospitalisation facilities. 98.4% of the city's population have access to at least 1 private or government hospital within 3 km (Figure 4.11). Considering the ease of accessibility to government run hospitals, especially for the low-income group, spatial analysis of the slum locations with respect to the location of the government run hospitals was undertaken. It was found that 10 slum locations from Wards 1, 2, 4, 15, 38, 51, 55 do not have access to government healthcare facilities.

The 10 slum locations, with a cumulative population of 5,148 persons, are Arokyanathapuram (Ward 38), Jeilsingh nagar (Ward 51), Karaiiruppu (Ward 2), Palkattalai (Ward 1), R.S.A Nagar (Ward 2), Rajagopalapuram (Ward 55), Thiruvananthapuram Pottal (Ward 4), V.M. Chathram (Ward 38), Kamarajar Nagar Pottal (Ward 4), and MGR Nagar (Ward 15).

Methodology Used: Spatial analysis of government and private hospitals and their accessibility within 3 km service area radius around the hospitals has been considered for analysis.

Data Used: Location of the private and government hospitals.



Climate Risk and Vulnerability Assessment

5.1 Introduction

An assessment of the risks and vulnerability of people, ecosystems and infrastructure to climate change is required to identify the nature and magnitude of the impacts of climate change on human society. At a local level, the vulnerability of urban population to climate change effects is often driven by unsustainable development patterns due to poor urban planning, land use, and governance. The vulnerability is higher for certain locations in a city and for certain groups of the population such as the low-income group, slum dwellers, elderly, and children. A Climate Risks and Vulnerability Assessment (CRVA) will highlight the significant variation in the climate impacts on different geographic area, demography, and the target sectors or systems.

At the city level, for Tirunelveli, a CRVA is key to identifying adaptation actions to enhance climate resilience of the city across various urban service sectors and infrastructure. Analysis of historical climate data, spatial information on urban geography and infrastructure, spatial dynamics of the city's demography are key to CRVA. However, poor availability of accurate data and spatial information limits the scope and depth of the assessment across sectors. Therefore, significant inputs from stakeholders who are part of the Climate Core Team and the Stakeholder Committee for climate action planning in TCMC were considered during the assessment. Further, sector-wise data available from the city's grievance redressal system was analysed along with stakeholder inputs to identify the vulnerable locations and urban service infrastructure in the city.

This chapter presents the results of the CRVA undertaken for Tirunelveli city based on the 'Towards Net-zero ClimateResilientCities' methodology (refer Chapter 2). The key components of the CRVA for Tirunelveli city are i) analysis of climate trends with respect to historical rainfall and temperature; ii) assessment of the risks due to climate hazards identified by Tirunelveli District's Disaster Management Plan, flooding, cloudbursts, and heat waves; and iii) vulnerability assessment of urban service sectors and climate impacts on population groups.

5.1.1 Methodology

The CRVA follows the 'Net-zero ClimateResilientCities Action Planning Methodology' of ICLEI South Asia. The methodology followed by TCMC for the CRVA is shown in Figure 5.1.

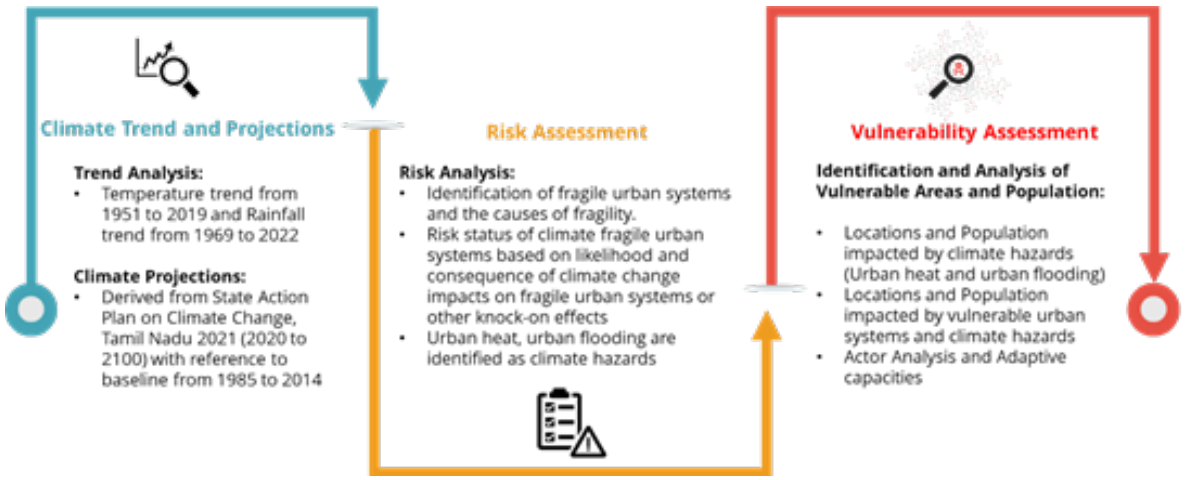


Figure 5.1: Methodology of Climate Risk and Vulnerability Assessment

5.2 Climate Trend and Projections

Table 5.1: Stipulated projects for transportation

Indicator	Methodology
Air Temperature Trend	Historic trend analysis of annual average minimum and maximum air temperature **Data Used:** Daily and yearly air temperature data from 1951 to 2019 **Data Source:** IMD, Tirunelveli
Rainfall Trend	Historic trend analysis of cumulative annual rainfall recorded at station level, rainy days, intensity, and frequency of extreme rainfall events **Data Used:** Daily rainfall data from 1969 to 2022 **Data Source:** IMD, Tirunelveli

5.2.1 Air Temperature Trend Analysis

An analysis of annual average maximum and minimum air temperatures from 1951 to 2019 indicates that the maximum annual average maximum temperature is 32.0°C and the annual average minimum temperature is 23.2°C. The maximum air temperature has increased by 1.34°C, while the minimum air temperature has increased by 0.6°C during the period of analysis (Figure 5.2).

5.2.2 Rainfall Trend Analysis

Annual rainfall recorded for Tirunelveli shows an increasing trend for the period 1969 to 2022 (Figure5.1)

The average annual rainfall for Tirunelveli in the period is 697 mm; the decadal average of annual rainfall received by Tirunelveli decreases by an average of 12 mm per decade from 1971 to 2020 (average 48 mm decrease from 1971 to 2020), with an increase in rainy days, showing higher number of low intensity rainfall days. However, in the last decade, the city experienced 33 heavy rainfall events and the annual rainfall recorded increased by an average of 272 mm in 2014, 2015, 2017, 2019, and 2021.

Tirunelveli observed, on average, 54 rainy days during the period but in the last decade, the average total number of rainy days has increased by 15%, with an average of 62 rainy days from 2011 to 2020. The last decade also witnessed extreme rainfall events of more than 100 mm rainfall received within 24 hrs in 2015, 2019 and 2021.

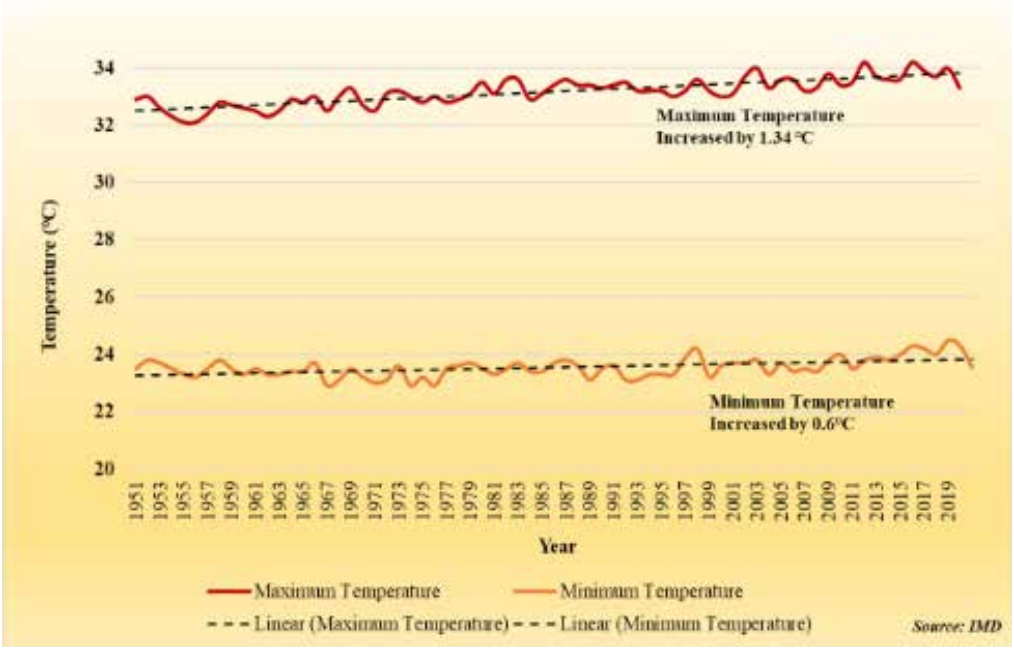


Figure 5.2: Average Air Temperature Trend in Tirunelveli (1951 to 2019)
Source: Analysis by Climate Studio, Anna University, Tamil Nadu, using IMD data

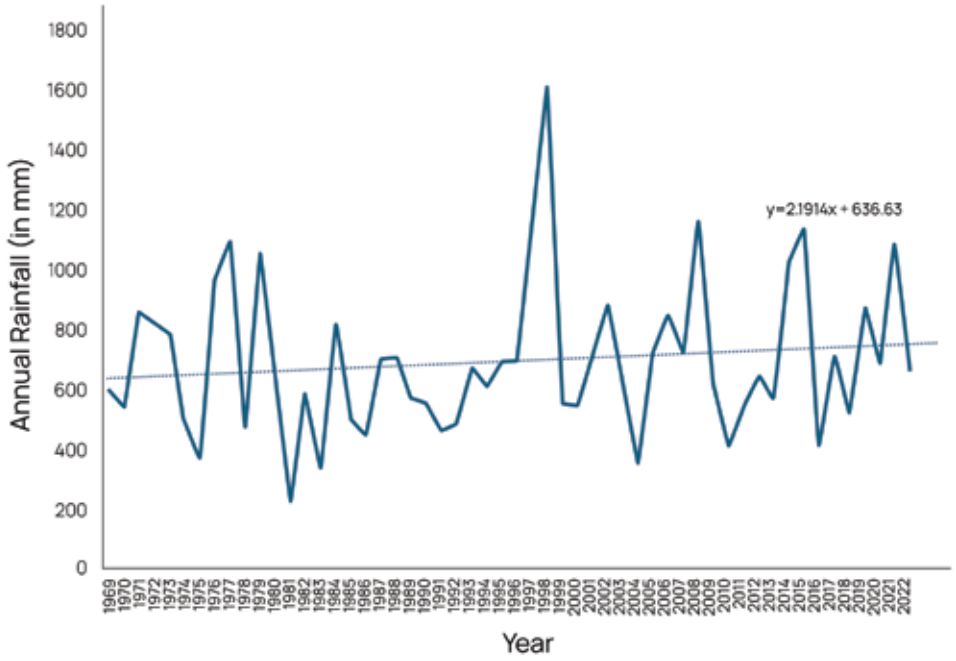


Figure 5.3: Annual rainfall trend in Tirunelveli (1969 to 2022)
Source: Analysis by ICLEI South Asia, based on data received from IMD

5.2.3 Climate Projections and Scenario Statements

The revised draft Tamil Nadu State Action Plan on Climate Change incorporates climate projections based on Shared Socio-economic Pathways (SSP) 2 and SSP 5 scenarios. The projections were modelled for the near-century (2020-2046), mid-century (2047-2073), and end-of-century (2074-2100) periods.

The SSP5 8.5 Scenario envisions significant advancements in human development, with substantial investments in education and health, rapid economic growth, and effective institutions. However, it relies heavily on an energy-intensive, fossil fuel-based economy. CO2 emissions are projected to double by 2050 and again by 2100 compared to current levels, leading to substantial global warming above 4°C. It is considered an optimistic scenario for human development but with high environmental costs due to increased fossil fuel consumption.

The SSP2 4.5 Scenario is referred to as the "middle of the road" scenario, and SSP2 assumes that historical patterns of development continue throughout the 21st century. The GHG emissions remain at current levels until the middle of the century, with moderate economic and population growth, and no major shifts in technology or policy. This scenario represents a balance between sustainability and continued economic development without drastic changes in energy policies or practices.

These scenarios have been utilized to project temperature and rainfall changes for Tirunelveli[1], providing critical information for developing local climate adaptation strategies. The projections under these scenarios help in understanding the potential impacts of climate change on the region and in planning accordingly to enhance resilience and sustainability. Table 5.1 and Table 5.2 shows the projections for annual average of temperature and rainfall for Tirunelveli.

Table 5.2: Annual Average Temperature Projections (Baseline: 1985 – 2014)

Projection Period	Increase in Annual Average Maximum Temperature (°C)		Increase in Annual Average Minimum Temperature (°C)	
	SSP2 4.5 Scenario	SSP5 8.5 Scenario	SSP2 4.5 Scenario	SSP5 8.5 Scenario
Near Century (2020 – 2046)	0.2	0.5	0.4	0.5
Mid Century (2047 – 2073)	0.5	0.8	0.8	1.2
End Century (2074 – 2100)	0.7	1.8	1.1	2.3

Source: Analysis by Climate Studio, Anna University, for Tirunelveli district

Table 5.3 Annual Average Rainfall Projections for Tirunelveli (Baseline: 1985 – 2014)

Projection Period	SSP2 4.5 Scenario		
	Near Century (2020 - 2046)	Mid Century (2047 - 2073)	End Century (2074 - 2100)
Percentage Change in Annual Average Rainfall (%)	6.6	15.4	19.3

[1] Climate Projections by Climate Studio, Anna University, Tamil Nadu, using data from IMD.

Temperature projections reveal that under the SSP5 8.5 scenario, the annual average maximum temperature increases by 1.8°C at the end of century while in the SSP2 4.5 scenario, it increases only by 0.7°C. Similarly, the annual average minimum temperature projections show that it increases by 2.3°C towards end of century in the SSP5 8.5 scenario while it increases by only 1.1°C towards end of century in the SSP2 4.5 scenario. Analysis of precipitation patterns in this century based on historical trends between 1985 to 2014 show that the annual average rainfall increases by 15.4% mid-century before peaking at 19.3% towards end of century based on SSP2 4.5 scenario.

Climate Scenario Statements:

Climate Risk 1: Average temperatures, heat wave events and number of hot days and nights may increase in future.

Climate Risk 2: Total rainfall and extreme rainfall events are expected to increase in future.

5.3 Climate Risk and Vulnerability Assessment

Climate linked hazards faced by Tirunelveli city are floods, cloud bursts and heatwaves. The city is prone to flash floods from Thamirabharani River that passes through the city, during times of heavy rainfall in the upper catchment areas of the river leading to heavy discharge from Manimuthar, Papanasam and Gadana dams. The city lies in the moderate damage risk zone for wind and cyclone hazards in the state[2] and faces the risk of urban flooding during cloudbursts or widespread heavy rainfall caused by cyclonic events in the Bay of Bengal during Northeast Monsoon.

Based on historic trends and projections for rainfall and temperature in the city, the future impacts of these climate parameters were identified. The level of risk and the likelihood of occurrence of these climate risks were analysed and their consequences on the critical urban systems were assessed. GIS based spatial analysis of various urban systems and their infrastructure, quantitative ward-wise data on urban system grievances, and qualitative information from consultations with relevant stakeholders from TCMC and other government agencies informed the CRVA.
Based on an analysis of the climate data in Section 5.2, it is evident that Tirunelveli is susceptible to impacts of both high intensity rainfall events and rising temperatures i.e., urban flooding and urban heat. The Tirunelveli District Disaster Management Plan (2021) recognises these climate hazards as potential disasters, further corroborated by the district level composite risk index of the draft TNSAPCC 2.0.

This exercise is aimed at evaluating the risk from climate hazards such as urban heat and urban flooding based on the fragility of urban systems to these hazards and impacts on various population groups in the city. Fragile urban systems identified as high-risk status were further investigated to identify hotspots, specific causes and impacted populations and locations within the city.

5.3.1 Climate Risk and Fragile Urban Systems

The climate resilience and vulnerability of Tirunelveli's urban systems were evaluated by examining the current service levels and baseline conditions of the city's infrastructure, considering the direct and indirect effects of identified climate hazards such as urban heat and urban flooding. The risks related to the vulnerabilities of these systems were assessed based on their likelihood and impact. For instance, increased heat could alter water consumption patterns, while urban flooding might contaminate water in areas where the supply network is already compromised.

Fragile urban systems and prevalent climate hazards significantly impact the city and its residents, as detailed in the climate fragility statements. These statements assess the risk by estimating the likelihood and consequences of these impacts on urban systems and populations. The risk assessment involved in-person discussions with key TCMC officials and Stakeholder Committee members. The criticality of fragile urban systems, existing and anticipated issues due to climate hazards, and defined fragility statements for Tirunelveli are presented in Table 5.3.

[2] https://www.tnsdma.tn.gov.in/app/webroot/img/document/map/cyclonehazard.pdf. Accessed September 2023.

Table 5.4: Critical Urban Systems and Climate Fragility Statements

Urban system	Why is it critical or fragile?
Water Supply	• High dependence on water supply from single source that is Thamirabarani River and on ground water resources • Increased stress on existing water supply system with increasing demand • High dependence on ground water during supply disruptions, and no regulation on ground water extraction both by individual households or private water suppliers • Limited interventions for ground water recharge; Ground water recharge pits implemented in 2020 are defunct now. • Complaints related to leakage in pipelines and limited/no water supply are recorded in some wards especially in the extension areas of the city where new developments are taking place. • Headworks and water pumping stations are impacted during river flooding events leading to severe supply disruptions. • Complaints related to water borne diseases are recorded from areas impacted by urban flooding during heavy rainfall events, especially in the older parts of the city.
Wastewater	• Lack of sufficient UGSS coverage in the city as only around 19% households are connected to UGSS in 2022-23 under Phase I of UGSS. Phases II and III of UGSS scheme are under implementation. • Challenges in implementing household connections to UGSS network in already implemented areas • Open drains carrying sewage from areas not covered by UGSS are led to nearby lakes or to Thamirabharani River. • Breakdown and leakage of old sewer pipelines, especially in older parts of the city and in areas with defunct sewerage system implemented by TNUHDB such as Anbu Nagar and Mahilchi Nagar • Drainage network manholes are opened during extreme rainfall events to reduce stormwater runoff, but this increases pressure on sewerage network.

Existing and anticipated problems caused by the fragility of this system	Responsibility	Climate Fragility Statement
• No alternative source available/assessed for water supply • Impact on water supply during flooding in river • No. of headworks insufficient to cater to increasing demand • Depleting ground water resource • Increasing incidence of water borne diseases due to contaminated water, especially in old town areas vulnerable to flooding	Engineering Department, TCMC, and TWAD Board	Abnormally high ambient temperatures experienced during extreme heat events may lead to increased water demand, thus burdening the water supply system of Tirunelveli that often faces water supply disruptions in the summer months or pre-monsoon period. Disruptions in water supply led to increased ground water extraction and low ground water levels during pre-monsoon period. This is especially the case post drought years when monsoon has partially failed and water supply from Thamirabarani River is limited. Increase in high intensity rainfall, leading to urban flooding, disrupts vulnerable infrastructure of the water supply and distribution system, impacting public health.
• Contamination of waterbodies including Thamirabharani River, the lifeline of the city, due to disposal of untreated sewage • STP functioning under capacity due to lower collection of sewage water from households • Increased incidences of sewage backflow due to blocked/pressurised sewerage network • Compromised sewage treatment due to dilution with rainwater	Engineering Department, TCMC and TWAD Board	Flooding events cause mixing of wastewater from open drains with stormwater and can lead to severe health impacts. Increased urban flooding events also exacerbate the problems caused by old sewerage networks, which impacts public health and quality of ground water and surface water. Optimal functioning of the UGSS network and STP is impacted due to diluted wastewater collection and high pressure due to excess flow of wastewater into the network.

Urban system	Why is it critical or fragile?
Solid Waste	• Littering and open dumping of waste, which tends to clog open stormwater drains and sewerage drains • Lack of source segregation leads to inefficient treatment of solid waste leading to under functioning of MCCs implemented across the city. • Open dumping of unprocessed solid waste due to limited treatment capacity • Leachate from open dumping locations within city are not treated or managed.
Transport	• Inadequate public transport fleet and lower route coverage of city areas • Limited first and last mile connectivity; Unorganised autorickshaws are expensive and safety measures are not enforced. • Inadequate NMT infrastructure • Traffic congestion due to limited parking facilities, vendor encroachment on roads and poor road infrastructure
Emergency Services	• 6.9% of the slum population faces limited accessibility to primary health centres and government hospitals, with distances exceeding 3 km. As a result, they are often compelled to use costly private healthcare facilities or suffer from increased risks of morbidity and mortality. • Accessibility to emergency services gets impacted due to urban flooding during extreme rainfall events.

Existing and anticipated problems caused by the fragility of this system	Responsibility	Climate Fragility Statement
• Increased stormwater and sewage network blockages • Increased chances of vector borne diseases • Increased ground water contamination by untreated leachate, also leading to unhygienic conditions for sanitary workers	Public Health Department, TCMC	Increased temperature accelerates decomposition rates and creates potentially hazardous conditions in the Ramayanpatti open dumpsite leading to increased probability of landfill fires, often witnessed during summer months. Sanitary workers are vulnerable to increasing heat stress, which reduces their productivity. UGSS network blockages due to solid waste accumulation increase during periods of high rainfall. Surface water and ground water sources are also contaminated due to increased leachate flows from the waste dumped in the open.
• Increased reliance on private vehicle modes of transport • Increasing air pollution • Regular congestion in major traffic junctions, especially during peak hours • Increased chances of road accidents: Cyclists and pedestrians are particularly vulnerable.	Tamil Nadu State Transport Corporation, Tirunelveli Engineering Department, TCMC Traffic Police	Increased extreme heat events limit the use of public transport and increase dependence on personal vehicles, leading to greater emissions. Increased temperatures may adversely impact the health of commuters, riders using two wheelers, pedestrians, and cyclists, especially elderly and children. Extreme rainfall events are likely to worsen the road infrastructure, and during such events, waterlogging on roads further exacerbates road congestion, affects connectivity, and leads to higher air pollution.
• Increased vulnerability for urban poor who face socio-economic impacts during extreme rainfall and urban heat events. • Increased vulnerability due to limited access to emergency services for urban poor and vulnerable population groups.	TNHUDB, Public Health and Engineering Departments, TCMC	Limited accessibility to emergency services for extreme heat related morbidities can lead to health risks for vulnerable populations such as the elderly, children, differently abled and people with pre-existing health conditions such as diabetes, cardiovascular diseases who are often prone to non-exertional heat stress leading to heat exhaustion or heat stroke. Increase in extreme rainfall and water

Urban system	Why is it critical or fragile?
Emergency Services	
Parks and Gardens	• The city has a green cover of about 27.51 sq. km, which is 25.32% of the city area. • 93 public parks and gardens with good accessibility but predominantly located in the eastern side of the city; Green cover is less in the western half of the city. • Highly dense residential and commercial developments surrounding the 4 urban centres of the city. • Increased built-up area with low permeability decreases percolation and diminishes ground water recharge.

The impacts of climate hazards on urban systems, identified in previous sections, are further evaluated. The risk score for each climate fragility statement is determined based on the likelihood of occurrence and the potential consequences. These details are presented in Table 5.4. The evaluation indicates that flooding will have a more significant impact on urban infrastructure than urban heat. However, for water-related facilities like water supply and sewerage systems, both flooding and heat pose serious threats, making them highly vulnerable. In the context of SWM, the impact of urban flooding is categorised as extreme, while that of urban heat is categorised as high. This information will guide and prioritise the interventions proposed in the climate action plan.

Existing and anticipated problems caused by the fragility of this system	Responsibility	Climate Fragility Statement
		logging may lead to disease outbreak, especially in congested slum locations. Limited accessibility to emergency services/facilities due to climate hazards increases the vulnerability of the urban poor.
• Urban heat island effects in densely developed areas. • Lower ground water recharge especially in the western areas of the city due to lower green cover and impermeable areas.	Planning and Engineering Departments, TCMC	Increasing heat risks may intensify urban heat island impacts during extreme events due to expanding built-up areas. Increased extreme rainfall events lead to urban flooding with increase in impermeable surfaces in the developed areas of the city.

Table 5.5: Risk Scoring of Climate Fragility Statements of Urban Systems

Urban Systems	Climate Fragility Statements
Water Supply	Abnormally high ambient temperatures experienced during extreme heat events may lead to increased water demand, thus burdening the water supply system of Tirunelveli that often faces water supply disruptions in the summer months or pre-monsoon period.
	Increase in high intensity rainfall, leading to urban flooding, disrupts vulnerable infrastructure of the water supply and distribution system, impacting public health.
Wastewater	Flooding events cause mixing of wastewater from open drains with stormwater and can lead to severe health impacts. Increased urban flooding events also exacerbate the problems caused by old sewerage networks, which impacts public health and quality of ground water and surface water. Optimal functioning of the UGSS network and STP is impacted due to diluted wastewater collection and high pressure due to excess flow of wastewater into the network.
Solid Waste	Increased temperature accelerates decomposition rates and creates potentially hazardous conditions in the Ramayanpatti open dumpsite leading to increased probability of landfill fires, often witnessed during summer months. Sanitary workers are vulnerable to increasing heat stress, which reduces their productivity.
	UGSS network blockages due to solid waste accumulation increase during periods of high rainfall. Surface water and ground water sources are also contaminated due to increased leachate flows from the waste dumped in the open.

Likelihood (a)	Consequence (b)	Risk Score (a x b)	Risk Status
Probability of occurrence of an event Almost certain - 5 Likely - 4 Possible - 3 Unlikely - 2 Rare - 1	Impact of an event Catastrophic - 5 Major - 4 Moderate - 3 Minor - 2 Insignificant - 1	Risk = Likelihood * Consequence	Extreme: >15 High: 11 - 15 Medium: 5 - 10 Low: <5
4	4	16	Extreme
4	3	12	High
4	4	16	Extreme
4	3	12	High
4	4	16	Extreme

Urban Systems	Climate Fragility Statements
Transport	Increased extreme heat events limit the use of public transport and increase dependence on personal vehicles, leading to greater emissions. Increased temperatures may adversely impact the health of commuters, riders using two wheelers, pedestrians, and cyclists, especially elderly and children.
	Extreme rainfall events are likely to worsen the road infrastructure, and during such events, waterlogging on roads further exacerbates road congestion, affects connectivity, and leads to higher air pollution.
Emergency Services	Limited accessibility to emergency services for extreme heat related morbidities can lead to health risks for vulnerable populations such as the elderly, children, differently abled and people with pre-existing health conditions such as diabetes, cardiovascular diseases who are often prone to non-exertional heat stress leading to heat exhaustion or heat stroke.
	Increase in extreme rainfall and water logging may lead to disease outbreak, especially in congested slum locations. Limited accessibility to emergency services/facilities due to climate hazards increases the vulnerability of the urban poor.
Public Parks and Gardens	Increasing heat risks may intensify urban heat island impacts during extreme heat events due to expanding built-up areas.
	Increased extreme rainfall events lead to urban flooding with increase in impermeable surfaces in the developed areas of the city.

Likelihood (a)	Consequence (b)	Risk Score (a x b)	Risk Status
Probability of occurrence of an event Almost certain - 5 Likely - 4 Possible - 3 Unlikely - 2 Rare - 1	Impact of an event Catastrophic - 5 Major - 4 Moderate - 3 Minor - 2 Insignificant - 1	Risk = Likelihood * Consequence	Extreme: >15 High: 11 - 15 Medium: 5 - 10 Low: <5
4	3	12	High
4	5	20	Extreme
3	3	9	Medium
4	3	12	High
3	3	9	Medium
3	4	12	High

5.3.2 Climate Vulnerability Assessment

Analysis of the land surface temperature (LST) was considered for identification of vulnerable hotspot areas. Data from TCMC on urban and riverine flooding locations from urban flooding management during historical events in the recent years and field assessments in the flood prone and low-lying areas helped identify the flood vulnerable points in Tirunelveli.

Table 5.6: Parameters Considered for Vulnerability Assessment

Climate Hazards	Parameters Considered for Vulnerability Assessment
Urban Heat	Surface temperature analysis and hotspot areas
Urban Flooding	Flooding/waterlogging points from historical events and field assessments for identification of causes

5.3.2.1 Vulnerability to Urban Heat Risks

LST is defined as the measure of how hot or cold the surface of earth gets during a specific period. It measures the emission of thermal radiance from the land surface where the energy from solar irradiation interacts with and heats the ground surface. Spatially continuous LST measurements retrieved from remotely sensed thermal-infrared (TIR) data available with satellite imagery that has global coverage allows examination of the thermal heterogeneity of the surface of earth at any location, and the impact on surface temperatures resulting from natural and human-induced changes.

LST will vary significantly across surfaces differentiated by types of soil, land-use, materials used in built-up areas, coverage of blue and green infrastructure, and due to various anthropogenic activities, such as in industrial or commercial areas. Specifically, daytime LST is more sensitive to the radiative and thermodynamic characteristics of the ground surface than standard air temperature measurements and is sensitive to changes in vegetation density. The change in daytime LST was assessed for May 2015, May 2018, May 2021, and May 2023 using satellite imagery. Annexure 5.1 shows the LST analysis for 2015, 2018, 2021 and 2023.

The median LST of 30.07°C in May 2023, the hottest month of the year, was considered as the threshold to identify LST hotspots in the city. Figure 5.5 shows

Table 5.7: Parameters Considered for Vulnerability Assessment

Climate Hazards	Parameters Considered for Vulnerability Assessment
Land Surface Temperature Analysis	Temporal analysis (pixel-based statistical analysis) of satellite imagery for day and nighttime for years 2015, 2018, 2021 and 2023 was conducted to understand the trend of LST. LST hotspots were identified and hotspot areas with higher LST as compared with median temperature above 30.07°C were considered. Data Used: Satellite imagery from May 2015, May 2018, May 2021 and May 2023 (May 2023 – daytime analysis considered for hotspot identification) Data Source: 1. Daytime Surface Temperature: 30X30m resolution LandSat8 image 2. Nighttime Surface Temperature: 30X30m resolution LandSat8 image

the hotspot areas in the city based on LST analysis in May 2023. It is observed that the newly developing areas, mostly on the eastern side of Thamirabarani River, with open and barren land parcels witness high LST during the day followed by areas with highly dense developments in the four zones of the city.

As is evident from the land-use pattern of Tirunelveli city, the residential and commercial development and accumulation of built-up area is concentrated in specific locations across the city while a significant part of the city area is still undeveloped, part of which is being used as agricultural lands. Due to this, Wards 1, 2, 3, 4, 14, 15, 29, 31, 46 with majority of their area covered under agriculture and other vegetation, experience low LST during the day ranging from 16.8°C to 30°C.

Urban Areas Vulnerable to High Surface Temperatures:

1. Newly developing areas in Wards 17, 18, 38, 39, 50, 51, 54, and 55 of Tirunelveli, Palayamkottai and Melapalayam zones, i.e., surrounding areas of Sivathipatti Road (towards south-east of Pushpalatha School), Darling Nagar, KTC Nagar, VM Chathram, Thirumal Nagar, Tuckerammalpuram, Anna Hajira College, Kokkattikulam Road, Cheranmahadevi Road (around Pettai Rail Nagar and Suthamalli), Tenkasi Road (around Rani Anna College and Palayapettai) etc.

2. Densely developed residential areas in and around the following locations:

   - Tirunelveli town area surrounding Nellaiappar Temple – Wards 24, 25, 28
   - Melapalayam town area surrounding Anna Veethi and Nethaji Road – Wards 44, 45, 47, 49
   - Pettai town area surrounding Cheranmahadevi Road – Wards 20, 21, 22
   - Tirunelveli Railway Junction and surrounding areas such as Balabackia Nagar, Selvi Nagar, Meenakshipuram, Kailasapuram – Wards 3, 12, 29, 30
   - Palayamkottai town and market area, South Bazaar Road, Tiruchendur Road and Sivalaperi Road, Murugankurichi, Shanthi Nagar, Samathanapuram, Manakavalampillai Nagar – Wards 6, 7, 9, 33, 34
   - Palayamkottai bus stand area, Pudhuppettai, Rajendran Nagar – Wards 32, 35
   - St. Thomas Road, Armed Reserve Force Quarters, Arul Nagar, Anna Nagar, MGR Nagar, Maharaja Nagar, Tirunelveli Medical College and Hospital – Wards 36, 39
   - Vannarpettai Junction area, Kokkirakulam, Barani Nagar, Vannarpettai – Wards 10, 11
   - Dr. MGR New Bus Stand area, Xavier Colony, Perumalpuram, Anbu Nagar – Wards 40,41, 42, 43

3. Densely developed commercial areas around Nellaiappar Temple, Palayamkottai Market, Pettai Main Road, Vannarpettai Junction, Tiruchendur Road, Trivandrum Road, New Bus Stand, Palayamkottai Bus Stand, Tirunelveli Railway Junction, Madurai Road-Town Road Junction, South Bypass Road (along Xavier Colony and New Bus Stand) and North Bypass Road (around Vannarpettai)

4. SIDCO industrial estate in Pettai

Extreme heat conditions can lead to multiple health and productivity impacts for a city's population that can in turn impact the city's sustainable economic development in future. High surface temperatures can cause thermal discomfort, impact productivity, increase heat related morbidities such as heat exhaustion and heatstroke. This may severely affect vulnerable population groups who are prone to heat exposure and reduced water supply during the hotter months of a year. Water demand increases during summer months and locations with poor water supply are severely impacted due to heat stress.

Extreme heat conditions significantly increase the energy demand in buildings during hotter months of a year due to higher space cooling and ventilation requirements. This directly stresses the power supply related infrastructure in the easter side of Tirunelveli city, especially the sub-stations from Samathanapuram, Thiyagarajanagar, Reddiyarpatti, Palayamkottai, and Melapalayam.

Population Groups Vulnerable to Extreme Heat:

Heat related morbidities can lead to health risks for vulnerable population in a city such as the elderly, children, differently abled and people with pre-existing health conditions such as diabetes, cardiovascular diseases who are often prone to non-exertional heat stress leading to heat exhaustion or heat stroke. On the other hand, exertional heat stress is common among hard-working labourers with continuous heat exposure, and low-income group or slum-dwelling

people with poor living and workplace conditions, and lack of affordable cooling options. Figure 5.6 shows the slum locations impacted by urban heat risks.

The vulnerable population groups such as the elderly and differently abled often face difficulties in accessing health infrastructure or emergency services in a timely manner at times of climate disasters such as heat waves. A dedicated communication channel for vulnerable groups is critical to improve awareness on heat related illnesses, and to provide timely access to community health centres/government hospitals and emergency services.

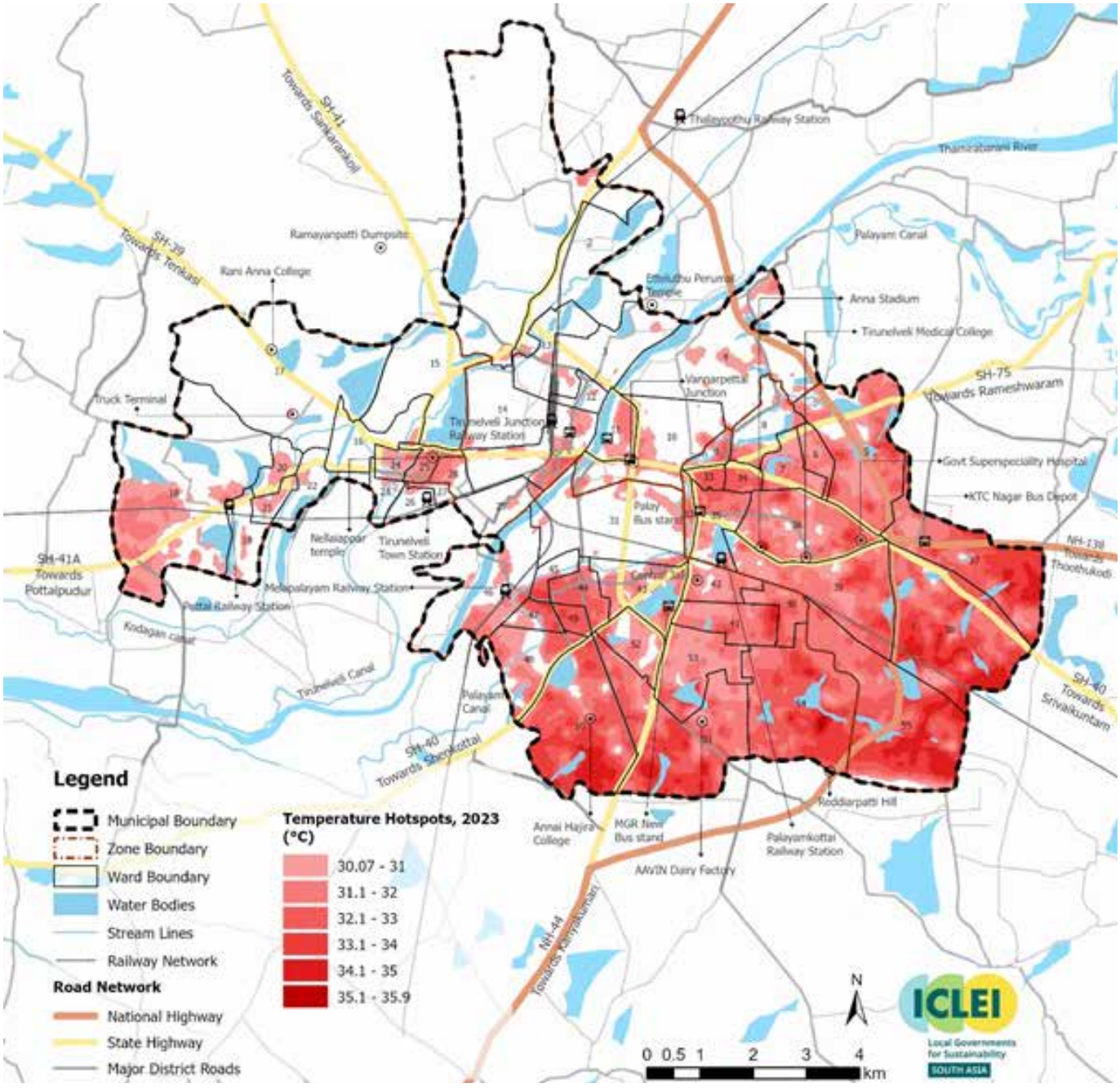


Figure 5.5: Land Surface Temperature Hotspot Areas, May 2023
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

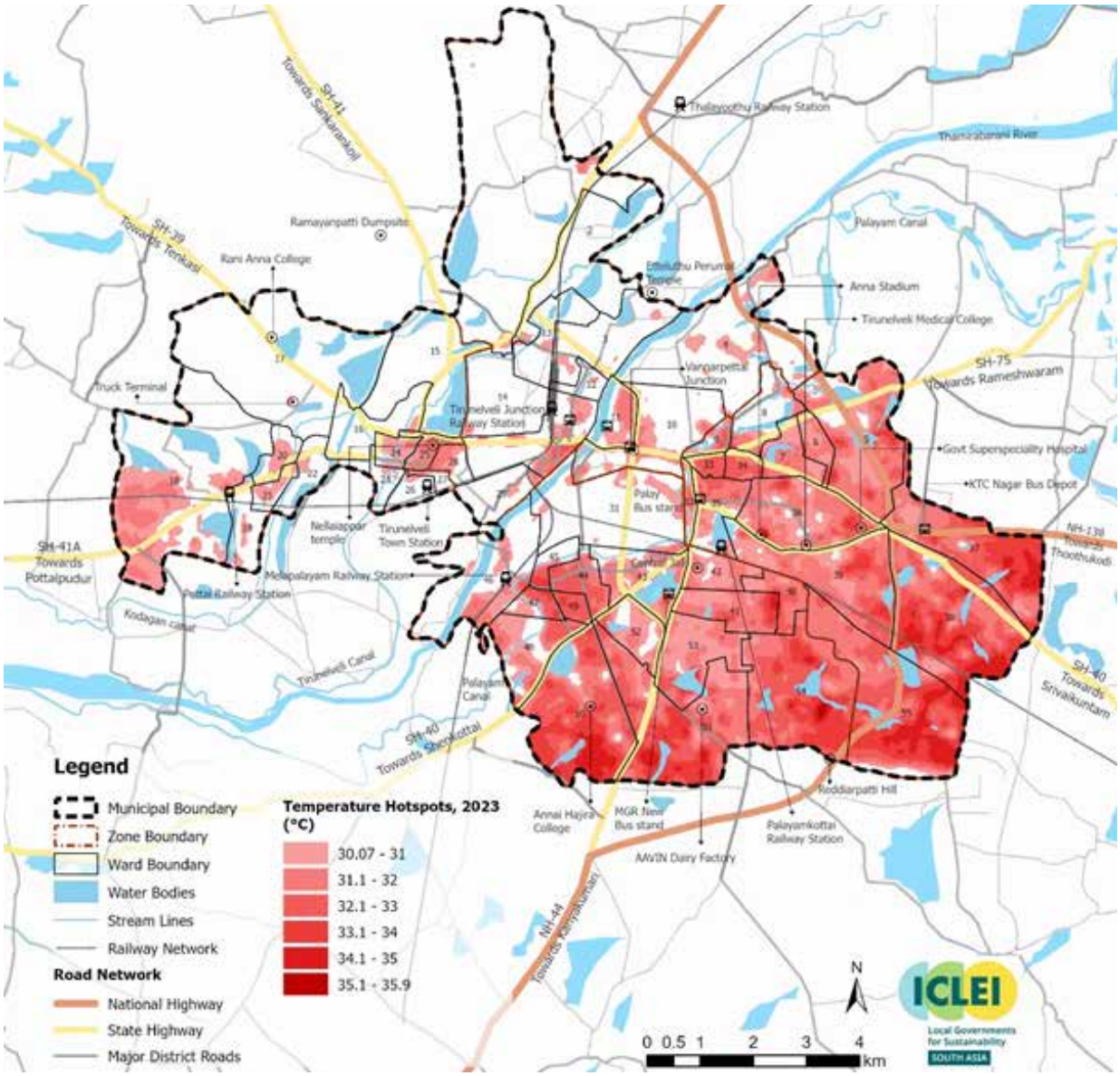


Figure 5.6: Slum Locations Vulnerable to Urban Heat Risk

Box 1: City Areas and Population Groups Vulnerable to Urban Heat

Land Surface Temperature Scenario: The LST analysis also shows that LST varies from 16.8°C to 35.9°C during the day over the assessment years 2015, 2018, 2021 and 2023.

Analysis of nighttime LST in 2021 and 2023 shows that LST varies from 25.6°C to 29.8°C during the night.

Maximum LST during the day increased from 31.8°C in 2018 to 35.9°C in 2023 while minimum LST increased from 16.8°C in 2018 to 25.6°C in 2023.

Hotspot Areas and Vulnerable Population:

51.27% of the total city area is identified as hotspot areas which recorded LST more than the median LST of 30.07°C. This impacts about 61.33% of Tirunelveli city's total population of about 554,522 estimated for 2021.

Population Groups Vulnerable to Heat Risk: [3]

Vulnerable population: 340,086 people (61.33% of the total population in the city)

Vulnerable population by age: 33,477 children are impacted by extreme heat risks

Vulnerable population by income group: 38,785 people living in slum locations are impacted by extreme heat hotspots (52.14% of the total slum population residing in 1.43% of city area)

[3] The values are estimated based on the population density of areas identified as hotspot areas; actual numbers may vary.

5.3.2.2 Vulnerability to Urban Flooding Risks

Tirunelveli city is vulnerable to urban flooding risks during extreme rainfall events in the city. This causes water stagnation in low-lying areas and other vulnerable locations across the city. The city is also prone to flash floods in Thamirabharani River basin due to heavy discharge from the Manimuthar, Papanasam and Gadana dams in the upper catchment areas that contribute significantly to water flow in the River which passes through the city for a stretch of about 17 km.

The key factors contributing to urban flooding in Tirunelveli are poor maintenance and inadequacy of existing stormwater drainage network, heavy siltation due to unauthorised solid waste and sewage disposal, encroachment of stormwater and irrigation drains and natural streams in the watershed areas of waterbodies in the city such as tanks, lakes and irrigation channels, and lack of development of a pucca stormwater drainage network in newly developing areas of the city.

The urban flooding risk assessment includes spatial mapping of 119 flood vulnerable locations identified across the city through field assessments and inputs from discussion with city officials, followed by a spatial analysis by overlaying them with the natural streams and waterbodies in the city, road network layers, slum locations and municipal infrastructure to understand the impact of urban flooding in various parts of the city. Figure 5.7 shows the spatially mapped flood vulnerable locations across the city.

Flood vulnerable locations identified in the city correspond to both river flood affected areas and low-lying areas where water stagnation issues persist, especially during heavy rainfall events. The spatial mapping of the flood vulnerable locations enables us to identify the most vulnerable areas or wards in the city that are prone to urban flooding risks. The wards with population living in low-lying areas along the riverbanks and irrigation canals flowing through the city and wards with more than 30% of the area covered under flood buffer zones are considered as the most flood vulnerable areas/wards in the city.

Urban Areas Vulnerable to Urban Flooding Risks:

Tirunelveli Zone: Wards 20, 21, 22, 23, 24, 25, 26, 27, 28, and 29 are vulnerable. Wards 20, 21, 22, 23, 24, 25 and 26 are also prone to flooding from Kodagan and Tirunelveli canals passing through the city, and Ward 29 located on the left bank of Thamirabarani River has low-lying areas prone to riverine flooding.

Thachanallur Zone: Wards 3, 10, 11, 12, and 30 are vulnerable. Wards 10, 11, 12 and 30 are also susceptible to flooding from Thamirabarani River. Wards 12 and 30 are high density developments that also witness severe waterlogging during heavy rainfall.

Palayamkottai Zone: Wards 5, 7, 32, 33, 34, 35, and 55 are vulnerable. Ward 32 is prone to flooding in Palayam canal and Ward 35 is often impacted due to stormwater overflowing from Elanthakulam which

Climate Hazards	Parameters Considered for Vulnerability Assessment
Locations prone to floods and water stagnation issues	Methodology Used: Analysis from satellite imagery using Digital Elevation Model. Natural contours and streamlines were overlaid with flood points, storm water network, road network, and built-up area (using Google Earth) layers. Flood vulnerable points were identified based on field visits and data from TCMC. Areas located within a 250 m buffer of the 119 flood points have been identified as flood vulnerable locations. Urban flooding risk is examined by analysing and correlating spatial information with qualitative information and data received from TCMC, and through stakeholder consultations. **Data Used:** Waterlogging Points (2021 & 2022) **Data Source:** 30X30m resolution LandSat8 image

receives stormwater runoff from nearby wards at higher elevation such as Wards 40, 41, and 42. Ward 55 has inadequate or poorly designed stormwater drains and encroachments along watershed areas of Rajagopalapuram lake.

Melapalayam Zone: Wards 40, 41, 42, 44, 45, 46, 47, 49, and 52 are vulnerable. Wards 44, 45 and 47 are prone to flooding in Palayam canal, while Ward 46 is susceptible to riverine flooding in Thamirabarani River.

Population Groups Vulnerable to Urban Flooding Risks:

Urban flooding is a major concern for developing cities as it affects the livelihood of low-income population in the city, causes health risks and significantly disrupts the daily life of the city population. The more vulnerable population groups such as the elderly, children, differently abled, and slum dwellers especially face severe impacts of urban flooding due to disruptions in their accessibility to urban services such as water supply, public transport etc. Further, households in slum locations have poor living conditions and face higher risks of epidemic due to water stagnation caused by heavy rainfall. Figure 5.8 shows the slum locations vulnerable to urban flooding in the city. Box 2 includes details on wards and population vulnerable to urban flooding risks in Tirunelveli.

Box 2: City Areas and Population Groups Vulnerable to Urban Flooding

Urban Flooding Situation: Areas within a 250 m buffer of the 119 flood vulnerable locations are considered as high-risk areas prone to urban flooding. People residing in these areas are vulnerable and may experience direct and indirect impacts of urban flooding.

Vulnerable City Area and Population: 15.58% of the total city area and 39.65% of total city population vulnerable to urban flooding in Tirunelveli in 2021

Vulnerable Wards: 31 wards face substantial risk of urban flooding in Tirunelveli:

Tirunelveli Zone: Wards 20, 21, 22, 23, 24, 25, 26, 27, 28, and 29

Thachanallur Zone: Wards 3, 10, 11, 12, and 30

Palayamkottai Zone: Wards 5, 7, 32, 33, 34, 35, and 55

Melapalayam Zone: Wards 40, 41, 42, 44, 45, 46, 47, 49, and 52

Population Groups Vulnerable to Urban Flooding Risk[4]

Vulnerable population: 219,872 people (39.65% of total population)

Vulnerable population by age: 21,643 children

Vulnerable population by income group: 22,403 people living in slum locations are impacted by urban flooding risks (30.16% of the total slum population living in 0.87% of city area)

[4] The values are estimated based on net population density of wards with flood vulnerable locations; the actual numbers may vary.

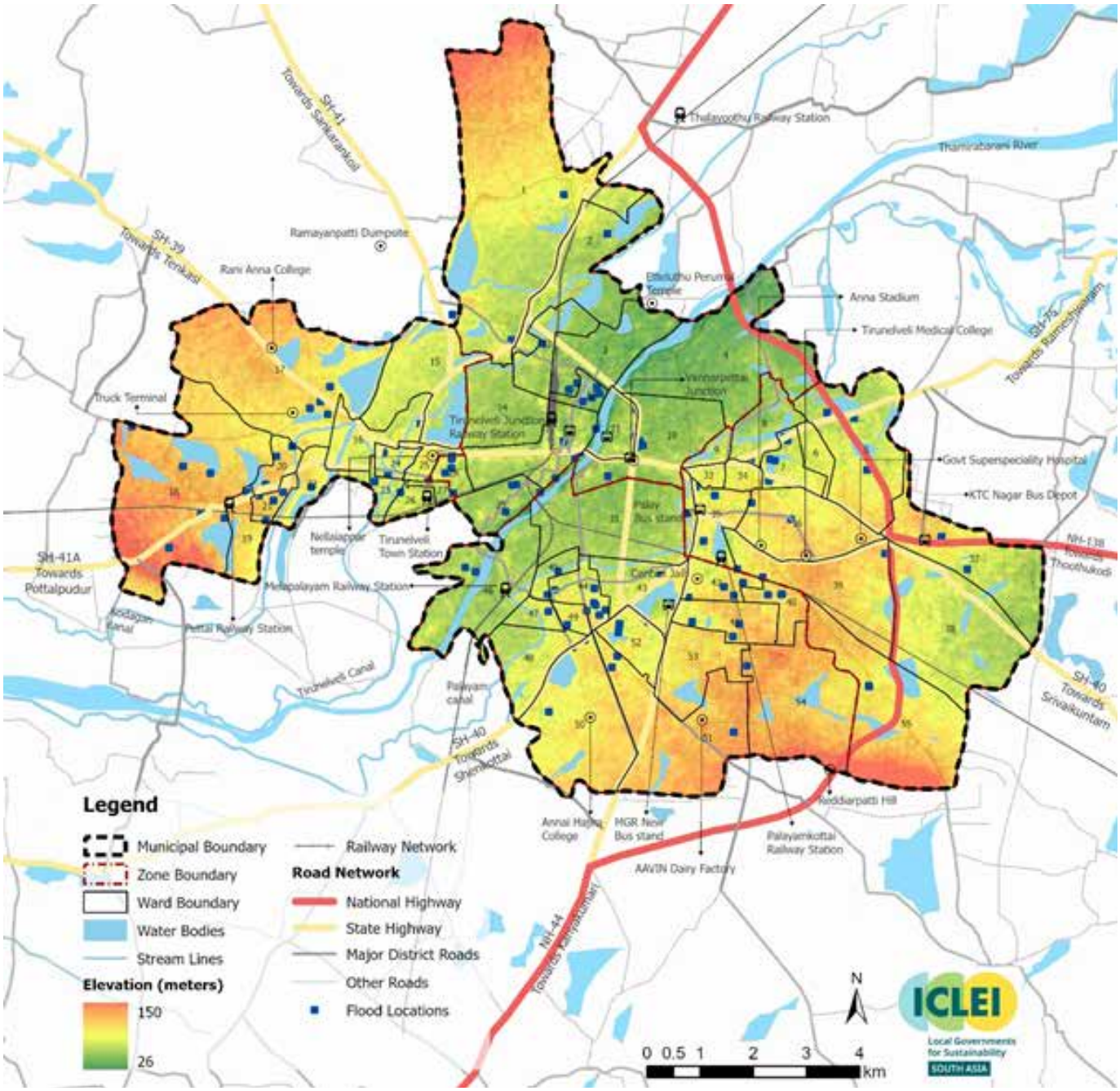


Figure 5.7: Flood Vulnerable Locations in Tirunelveli City
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

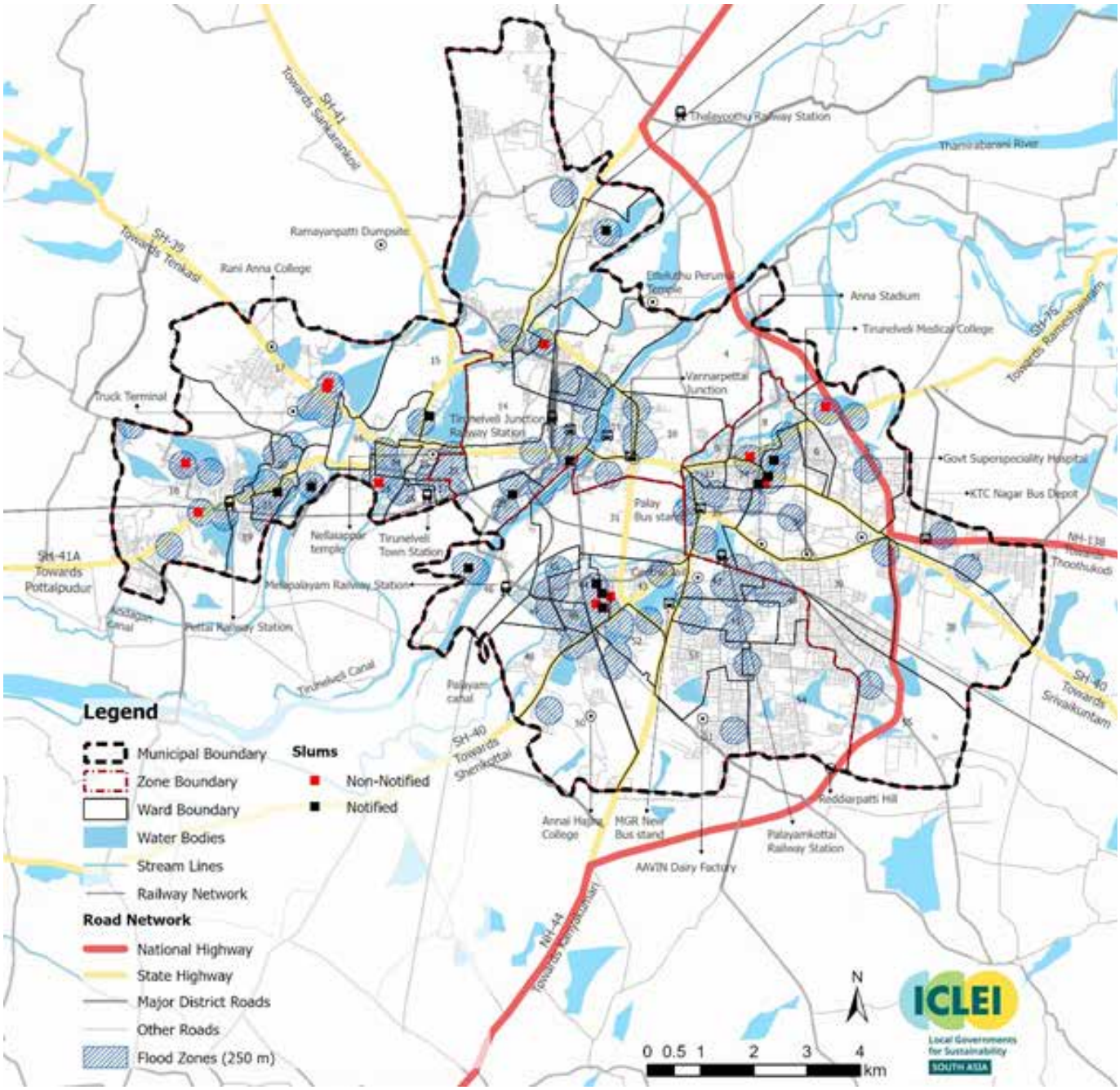


Figure 5.8: Slum Locations Vulnerable to Urban Flooding Risks
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

5.3.2.3 Vulnerability of Urban Service Systems and Infrastructure

The vulnerability of urban service systems to climate change was assessed through spatial analysis of urban service infrastructure with respect to climate risks such as extreme heat and rainfall events and based on stakeholder consultations with the Stakeholder Committee and the Climate Core Team. Based on the climate vulnerability assessment of the urban service system, the impact on city's population and infrastructure were identified to determine suitable actions to improve adaptability or urban infrastructure to climate change risks faced by the city.

Vulnerable population, locations in the city, and urban service infrastructure that will be impacted by climate risks were assessed based on spatial analysis of urban service infrastructure, locations prone to climate risks such as extreme heat and flooding events. Where possible, the issues highlighted by the grievance redressal system over the years 2019, 2020, 2021 and 2023 were correlated to arrive at vulnerable areas affected by maximum number of issues due to fragile urban systems and climate events.

Further, the adaptive capacity of vulnerable population and actors to climate change risks were assessed based on analysis of the capacity of different city actors to develop urban climate resilience, the ability to make effective plans based on evidentiary information, and the capacity of actors to mobilise resources and manpower to organise and respond to climate threats.

5.3.2.3.1 Water Supply

Vulnerability to Urban Heat Risks:

Locations in the city that fall under heat hotspots identified based on the LST analysis (refer Section 5.3.2.1) which also face water supply issues due to poor maintenance or lack of water distribution network will face higher risks during high heat events. Wards such as 37, 38, 51, 54, and 55 that are close to the city's southern and eastern boundaries are newly developing areas and have only partial water supply coverage. These wards are also vulnerable to urban heat risks and can witness water shortage issues during extreme heat events.

Although water supply coverage with respect to the households in Tirunelveli city is more than 90%, most of the households are dependent on ground water to supplement municipal water supply for their daily needs. This is due to limited supply of municipal water to households (only three hours daily); in 15 out of the 55 wards, municipal water is supplied only on alternate days or once in three days. Dependence on ground water poses huge risks for the city population as ground water table in the city is significantly lower in the pre-monsoon period especially during summer months.[5] This is further exacerbated by lower rainfall levels during monsoon season.

15 wards have been identified in Tirunelveli to be exposed to high temperature risks during summer months and witness high incidences of water supply related challenges. Box 3 includes details on the 15 wards vulnerable to water supply issues and urban heat risks.

Box 3: Vulnerability of Water Supply System to Urban Heat Risks

Vulnerable wards: 15 out of 55 wards (Wards 5, 6, 32, 36, 37, 38, 39, 40, 41, 42, 48, 51, 53, 54, and 55) are highly vulnerable.

Vulnerable population: 156,681 people living in the 15 vulnerable wards (28.26% of total city population)

Vulnerable population by income group: 9,065 people, including 2,647 people below poverty line, living in 15 slum locations across 8 of the 15 vulnerable wards (12.21% of total slum population living in 0.39% of city area)

[5] Refer Tirunelveli Watershed Assessment and Management Plan, prepared under CapaCITIES Phase II project

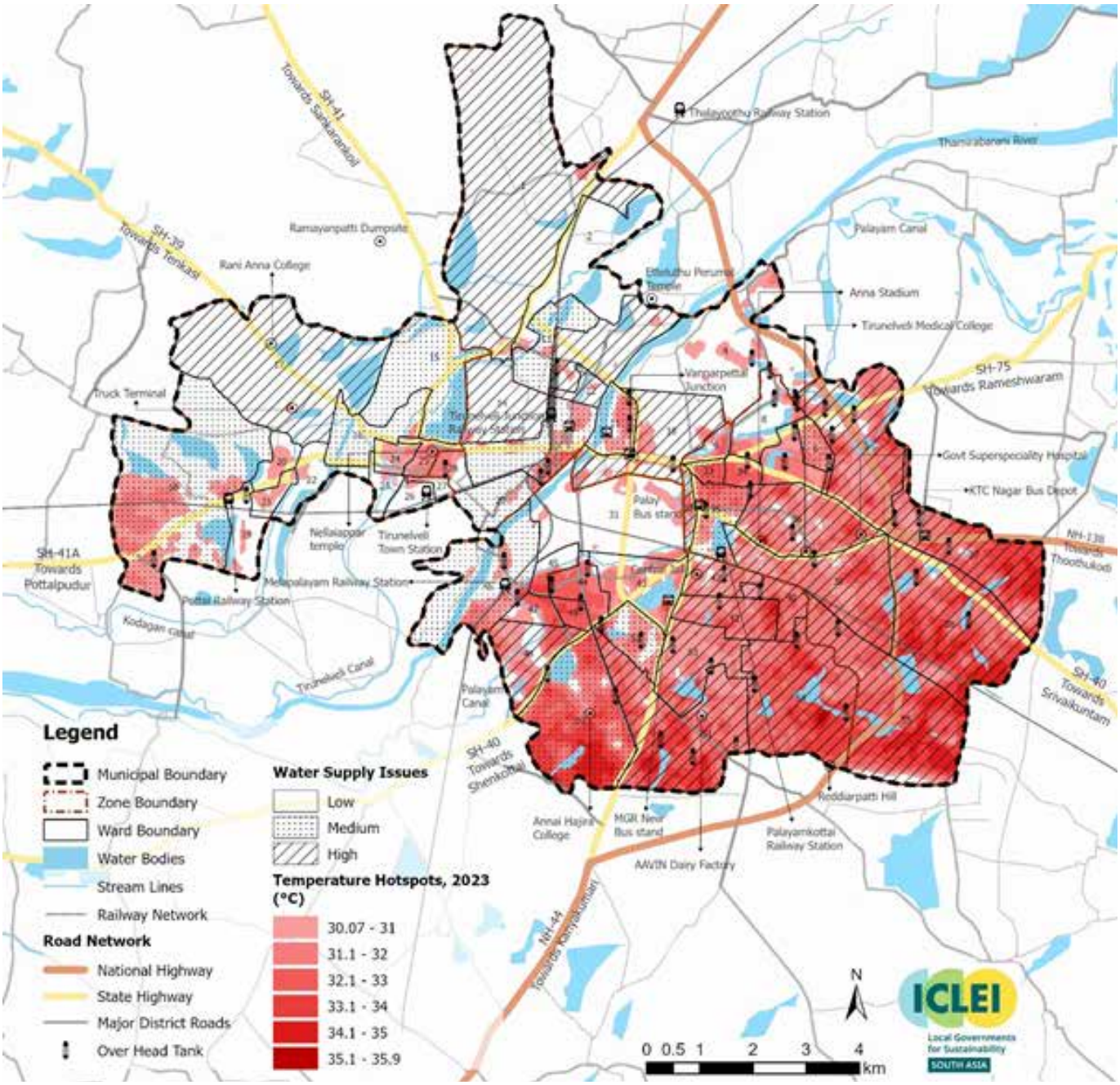


Figure 5.9: Wards Vulnerable to Urban Heat Risks and Water Supply Issues
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

Vulnerability to Urban Flooding Risks:

Due to lack of complete spatial data on Tirunelveli's water supply and distribution network infrastructure, the water supply pumping and distribution stations were spatially mapped and analysed for their vulnerability to urban flooding by correlating with the flood buffer zones of around 119 flood vulnerable locations identified in the city. Similarly, the wards with water supply issues such as leakage, contamination, and water shortage were analysed and mapped to identify vulnerable wards which are prone to urban flooding and water network issues (Figure 5.10).

20 wards with compromised infrastructure and high

incidence of water supply challenges such as leakages and contamination were identified as the wards vulnerable to water supply issues and urban flooding risks. Box 4 includes details on the wards vulnerable to water supply issues and urban flooding risks.

Box 4: Vulnerability of water supply sector to urban flooding risks.

Water supply infrastructure at risk: 29.76% (25 out of 84) of the OHT's that distribute water in the city are in flood vulnerable areas, and 3 pumping stations located at Karuppandurai, Kurukkuthurai and Theepatchiamman Temple face high risk of riverine flooding. All pumping stations located upstream and downstream of Tirunelveli on Thamirabarani riverbed are prone to riverine flooding risks which will directly impact water supply in the city.

Vulnerable wards: 20 out of 55 wards (Wards 3, 5, 7, 10, 11, 12, 17, 28, 29, 30, 32, 33, 35, 40, 41, 42, 44, 46, 51 and 52) are highly vulnerable.

Vulnerable population: 199,391 people living in the 20 vulnerable wards (35.96% of total city population)

Vulnerable population by income group: 24,196 slum population, including 9,063 people below poverty line, living in 24 slum locations across 13 out of the 20 vulnerable wards (32.58% of total slum population living in 0.90% of city area)

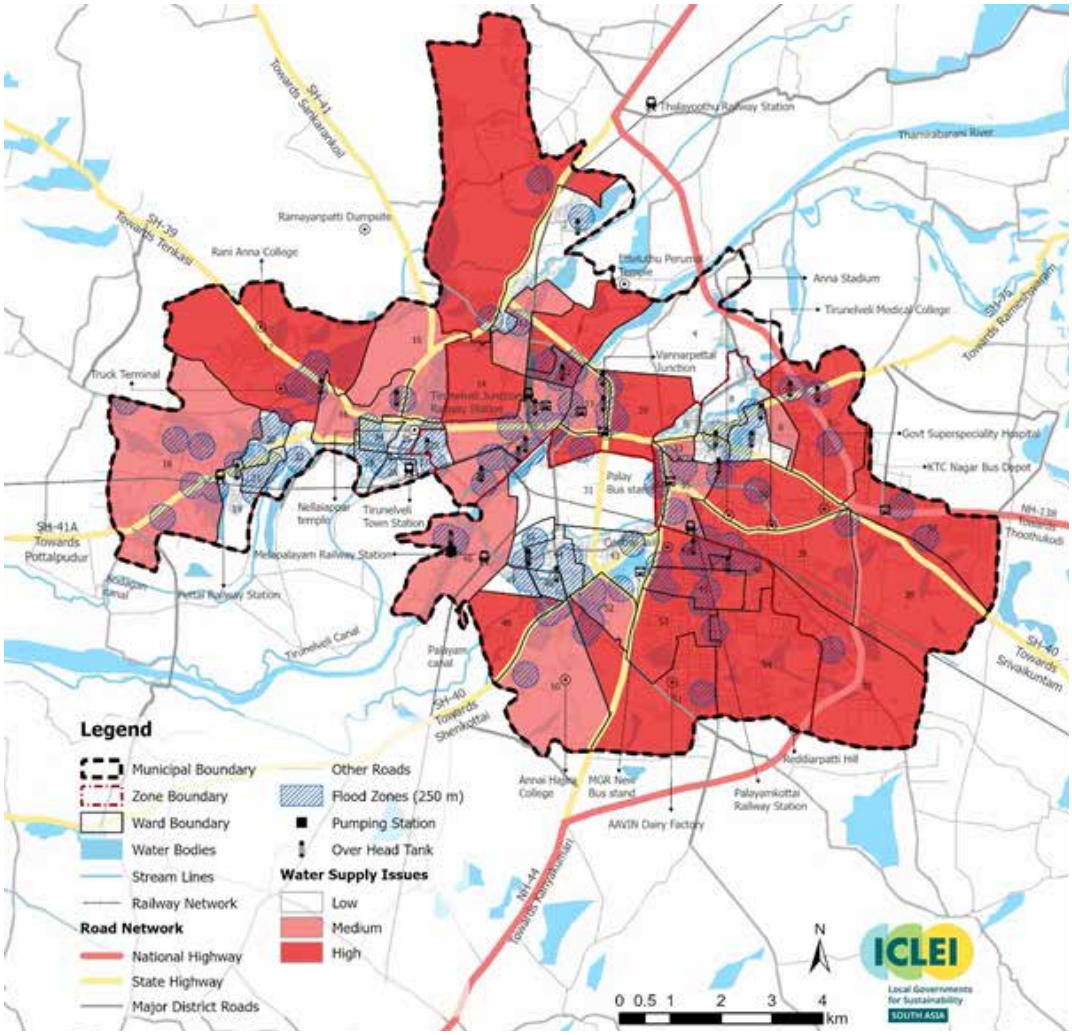


Figure 5.10: Wards Vulnerable to Urban Flooding Risks and Water Supply Issues
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

5.3.2.3.2 Wastewater Management

Tirunelveli UGSS network completed under Phase 1 is functional and covers only around 19% of the city's households. Implementation of Phase 2 and Phase 3 of UGSS network is on-going. Therefore, the grievances registered under wastewater management include complaints regarding existing issues such as blockages, damage and siltation in open sewers and stormwater drains. These issues also lead to deterioration in urban hygiene during times of flooding. The ward wise grievance data on wastewater management issues such as leakage, backflow or overflow, and contamination of stormwater was analysed to identify vulnerable wards and spatially mapped in conjunction with flood risk map of Tirunelveli.

13 wards with compromised wastewater management infrastructure and high or moderate level of grievances regarding wastewater management were identified as vulnerable to urban flooding and wastewater management challenges. Box 5 includes details on the wards vulnerable to wastewater management issues and urban flooding risks.

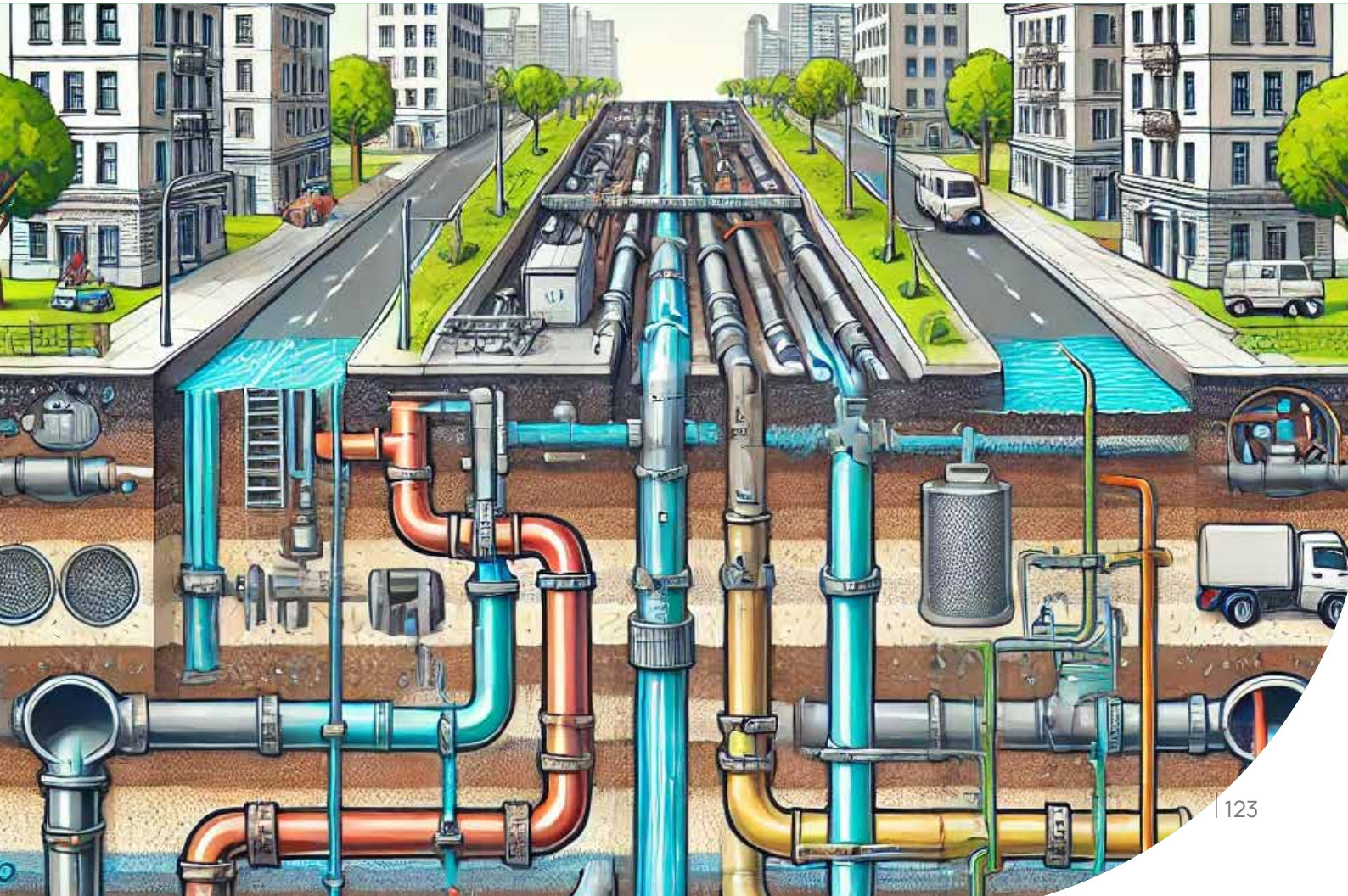
Box 5: Vulnerability of wastewater management sector to urban flooding risks.

Sewage pumping stations at risk: 2 out of the 4 sewage pumping stations, located in Balabackiya Nagar and Vannarapettai, are prone to urban flooding risks.

Vulnerable wards: 13 out of 55 wards (Wards 3, 7, 11, 12, 17, 21, 40, 41, 42, 43, 44, 52, and 55) are vulnerable to wastewater management related issues and urban flooding.

Vulnerable population: 128,203 people living in the 13 vulnerable wards (23.12% of total city population)

Vulnerable population by income group: 16,142 slum population, including 4,902 people below poverty line, living in 16 slum locations across 8 vulnerable wards (21.73% of total slum population living in 0.63% of city area)



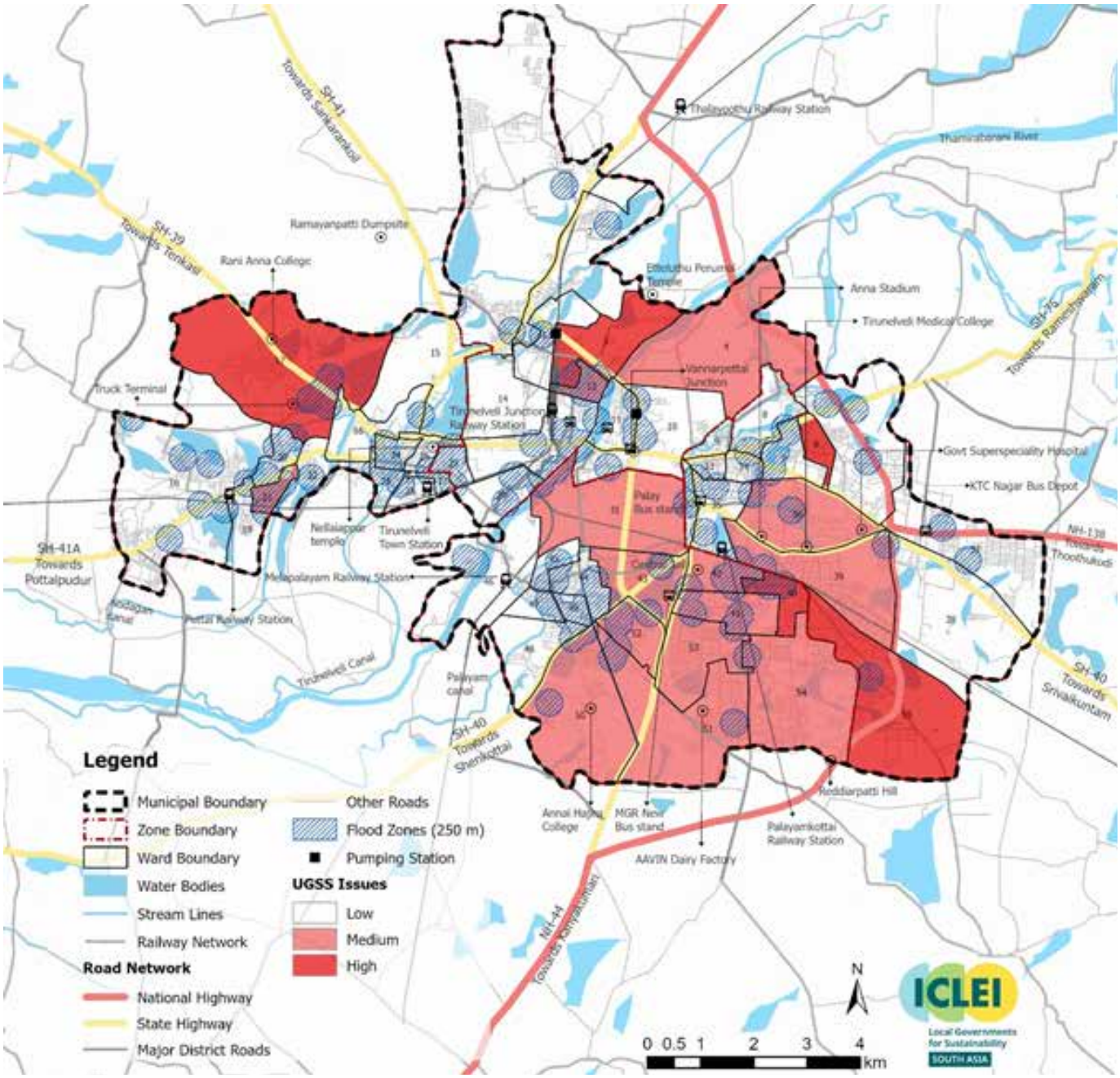


Figure 5.11: Wards Vulnerable to Urban Flooding Risks and Wastewater Management Issues
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

5.3.2.3.3 Solid Waste Management

Vulnerability of Solid Waste Management to Urban Flooding Risk:

SWM has been a challenge in Tirunelveli due to various inefficiencies leading to mismanagement of MSW. The mismanaged waste often ends up blocking open sewers and stormwater drains when entering the environment and cause or exacerbate waterlogging issues and create unhygienic conditions in public spaces. This can cause health risks such as water-borne and vector-borne diseases during monsoon season, and particularly after heavy rainfall.

SWM infrastructure was spatially mapped and correlated with flood risk map of Tirunelveli to identify the vulnerable infrastructure. Further, complaints related to littering, indiscriminate waste dumping and blockage of drains and manholes were analysed and correlated with areas impacted by urban flooding to identify wards vulnerable to both SWM issues and urban flooding risks (Figure 5.12).

20 vulnerable wards that receive relatively greater complaints in the grievance redressal system and having waste management infrastructure that can be compromised due to waterlogging issues were identified. Box 6 includes details on the wards that are both vulnerable to urban flooding risks and issues related to SWM.

Box 6: Vulnerability of Solid Waste Management Sector to Urban Flooding Risks

Vulnerable infrastructure: 4 MCCs and 6 on-site composting centres (10 out of the 47 in the city) are in flood prone areas.

Vulnerable wards: 20 wards (Wards 3, 5, 7, 10, 12, 20, 24, 25, 30, 33, 40, 41, 42, 43, 44, 45, 49, 51, 52, and 55) are vulnerable to both SWM issues and urban flooding risks.

Vulnerable population: 198,392 people living in 20 vulnerable wards (35.78% of total city population)

Vulnerable population by income group: 19,477 people, including 8,187 people below poverty line, living in 19 slum locations across 9 wards out of the 20 vulnerable wards (26.22% of total slum population living in 0.73% of city area)

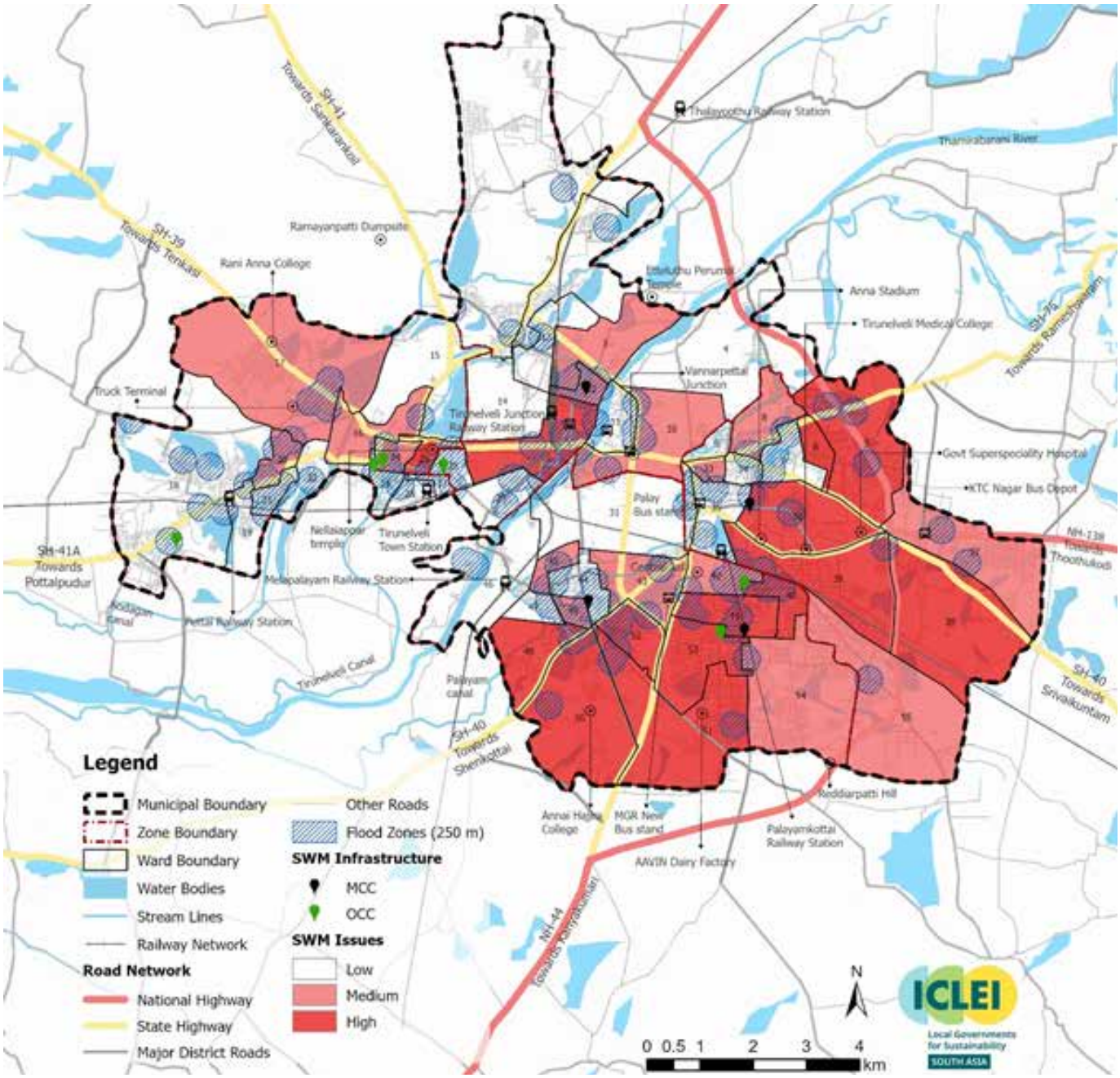


Figure 5.12: Wards Vulnerable to Urban Flooding Risks and Solid Waste Management Issues
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

5.3.2.3.4 Transport

Vulnerability of Transport Infrastructure to Heat Hotspots:

The existing public transport infrastructure in Tirunelveli is not adapted for use by public during heatwave events unlike climate-controlled private vehicles. People accessing public transport services from urban heat hotspot areas are vulnerable to heat stress, especially the elderly, children, and people with morbidities.

Spatial analysis of Tirunelveli's public transport infrastructure including bus stands, bus depots and bus stops was carried out in correlation with major traffic junctions and urban heat hotspot areas identified for Tirunelveli. Figure 5.13 shows the public transport infrastructure located in urban heat hotspots and Box 7 includes details on the impacted infrastructure.

Box 7: Vulnerability of Transport Sector to Urban Heat Risks

Vulnerable public transport infrastructure: All three public bus stations and all three bus depots in the city are in areas vulnerable to urban heat risks. Further, 83.12% of spatially mapped 77 bus stops (64 bus stops) are vulnerable to urban heat hotspots.

Vulnerable traffic junctions: All of the 17 major traffic junctions identified by Tirunelveli's Comprehensive Mobility Plan are in locations vulnerable to heat hotspots and 77.77% of the 45 traffic junctions/points (34 traffic junctions) are vulnerable to urban heat risks.

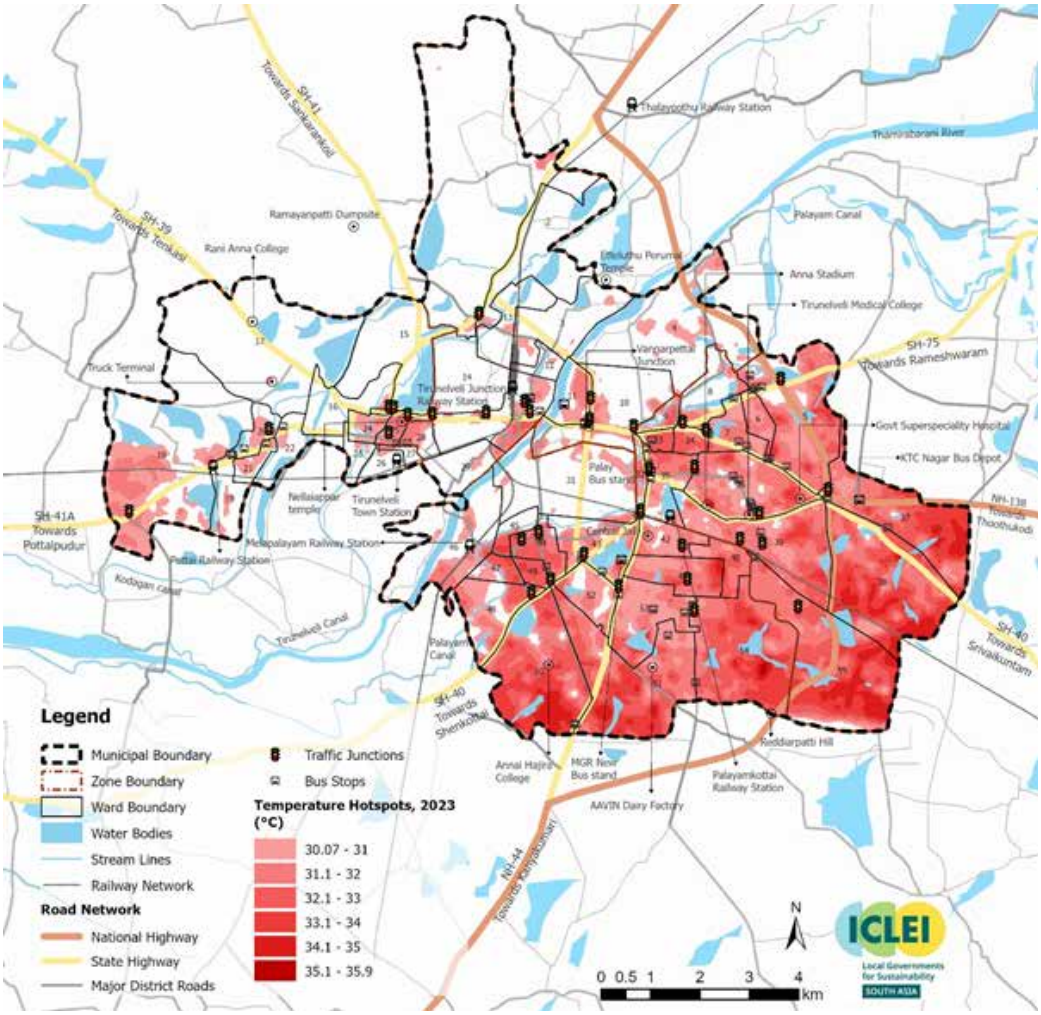


Figure 5.13: Transport Infrastructure Prone to Urban Heat Risks
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

Vulnerability of Transport infrastructure to Urban Flooding:

Apart from potentially compromising the public transport infrastructure and hindering mobility in major junctions, urban flooding may also significantly impact accessibility to public transport in wards with poorly maintained roads and that are vulnerable to urban flooding risks.

Public transport infrastructure such as bus stops, bus stands and bus depots, and the 44 traffic junctions in the city known for significant flow of traffic were spatially mapped and correlated with wards vulnerable to urban flooding risks. The spatial analysis (Figure 5.14) revealed that the Junction Periyar bus stand located near Tirunelveli railway junction and 35 bus stops are prone to urban flooding risks.

Spatial analysis of wards with appreciable number of issues pertaining to road network such as mediocre quality of roads, potholes, unpaved footpaths, and elevated/open manhole covers in correlation with flood vulnerability revealed that 7 wards had road network related issues in flood prone areas. Box 8 includes details on vulnerability of transport sector due to urban flooding risks.

Box 8: Vulnerability of Transport Sector to Urban Flooding Risks

Vulnerable bus stands and bus stops: 1 out of 3 public bus stations (Tirunelveli Junction Periyar bus stand) and 45.45% of 77 bus stops (35 bus stops) are vulnerable.

Vulnerable traffic junctions: 53.33% of the total 45 traffic junctions (24 traffic junctions including 6 major traffic junctions) are vulnerable to urban flooding risks.

Vulnerable wards: 7 wards (Wards 3, 5, 12, 23, 25, 27, 30) are vulnerable to both road network related issues and urban flooding risks.

Vulnerable population: 68,617 people living in the 7 vulnerable wards (12.37% of total city population)

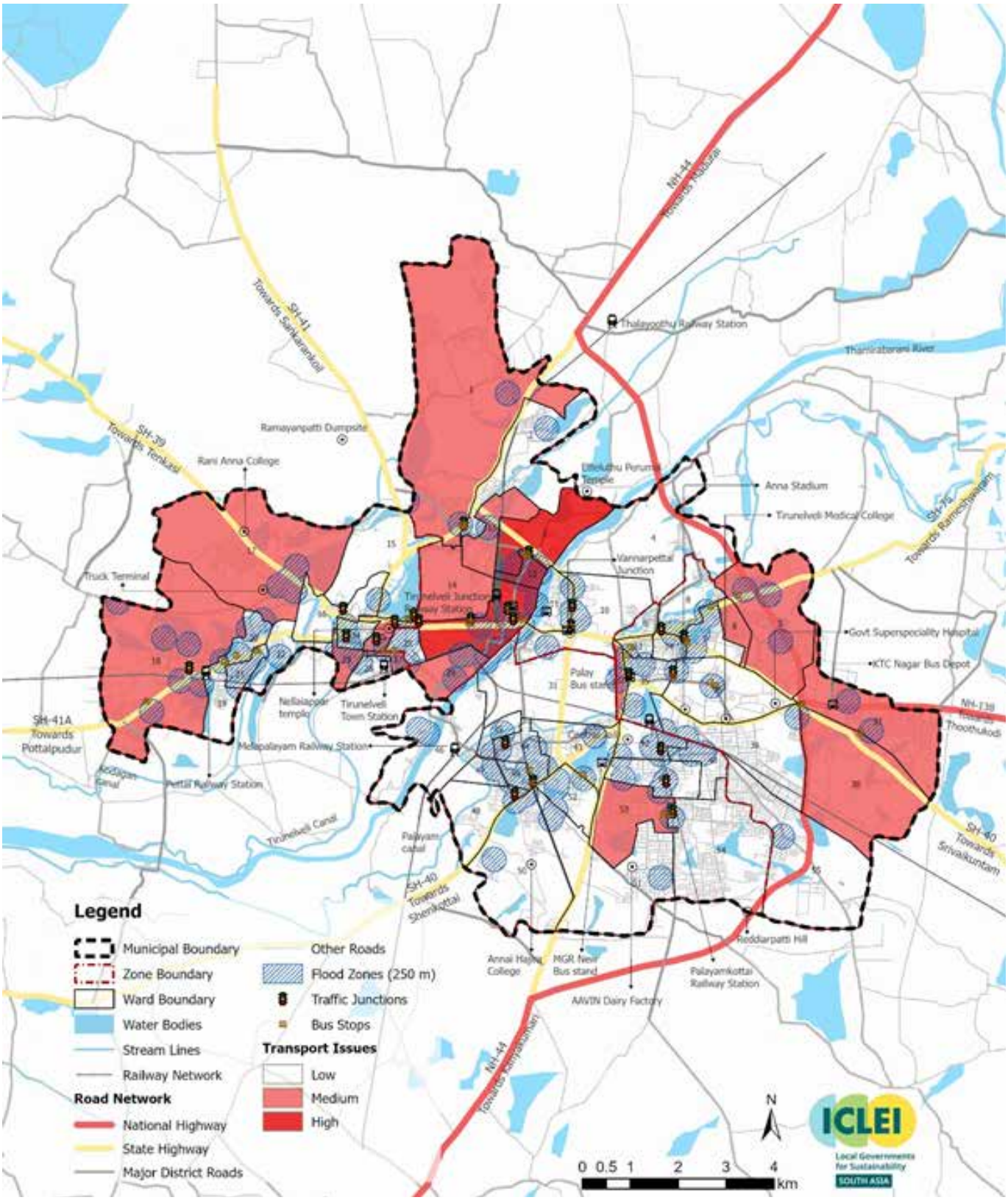


Figure 5.14: Wards Vulnerable to Urban Flooding Risks and Transport Network and Infrastructure Issues
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

5.3.2.3.5 Healthcare

Vulnerability of Healthcare Services to Urban Flood Risks:

To analyse the vulnerability of government and private hospitals in the city to urban flooding, the hospitals are spatially mapped and superimposed on flood risk map of the city prepared based on the identified 119 flood vulnerable locations (Figure 5.15).

Box 9 includes details on healthcare facilities vulnerable to urban flooding risks.

Box 9: Vulnerability of Healthcare Facilities to Urban Flooding Risks

Hospitals vulnerable to urban flooding risks: 48.57% of 105 hospitals (51 hospitals) in the city are vulnerable to impacts of urban flooding. Seven out of the 10 urban primary health centres and 2 out of the 6 government hospitals are in flood buffer zones.

Vulnerable wards: 7 Wards (Wards 10, 11, 16, 30, 31, 41, and 43) are vulnerable to urban flooding as 4 or more hospitals in these wards fall under flood impact areas identified in the city.

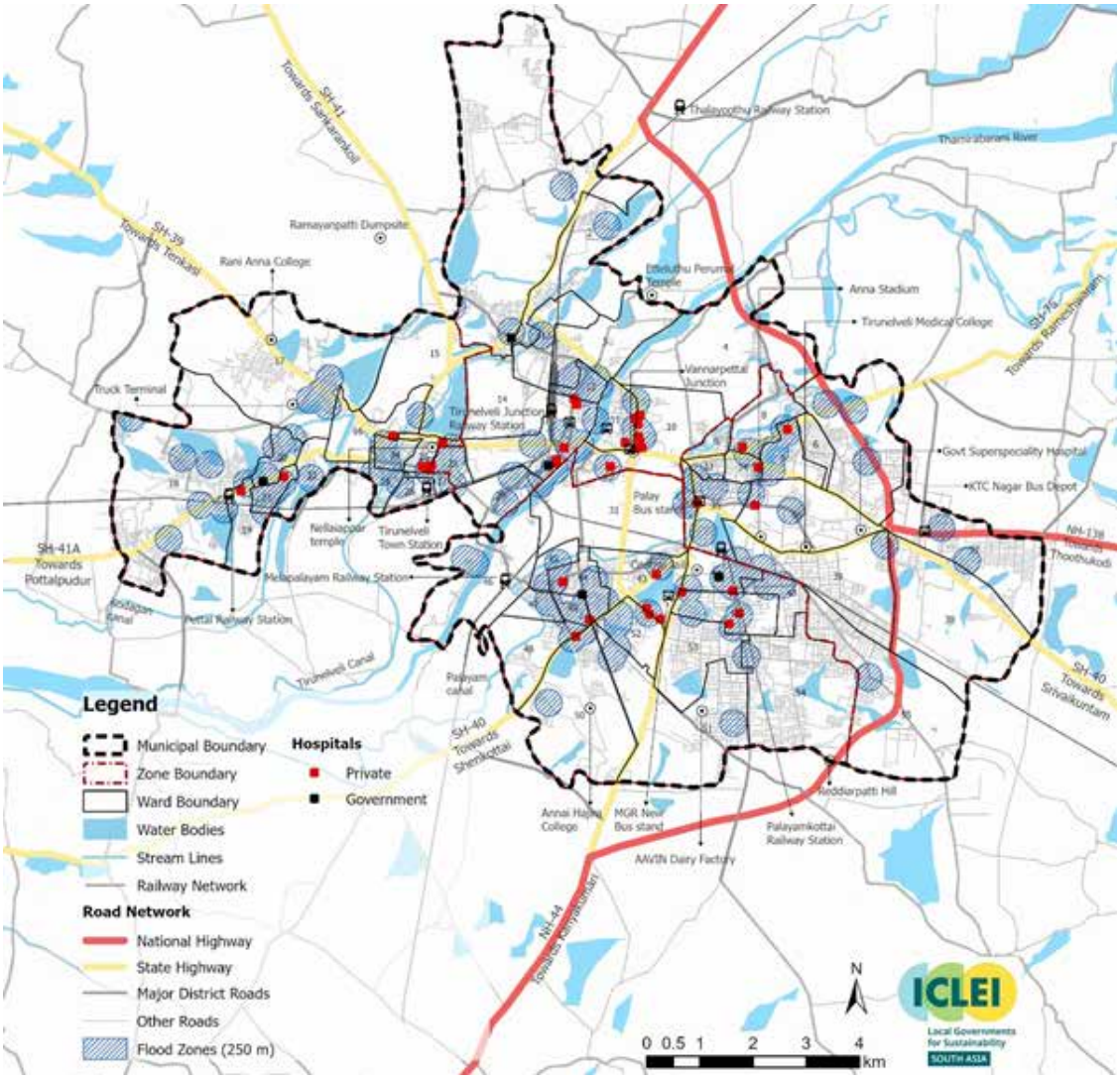


Figure 5.15: Government and Private Hospitals in Flood Prone Areas
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

5.3.2.4 Climate Vulnerable Hotspots in Tirunelveli

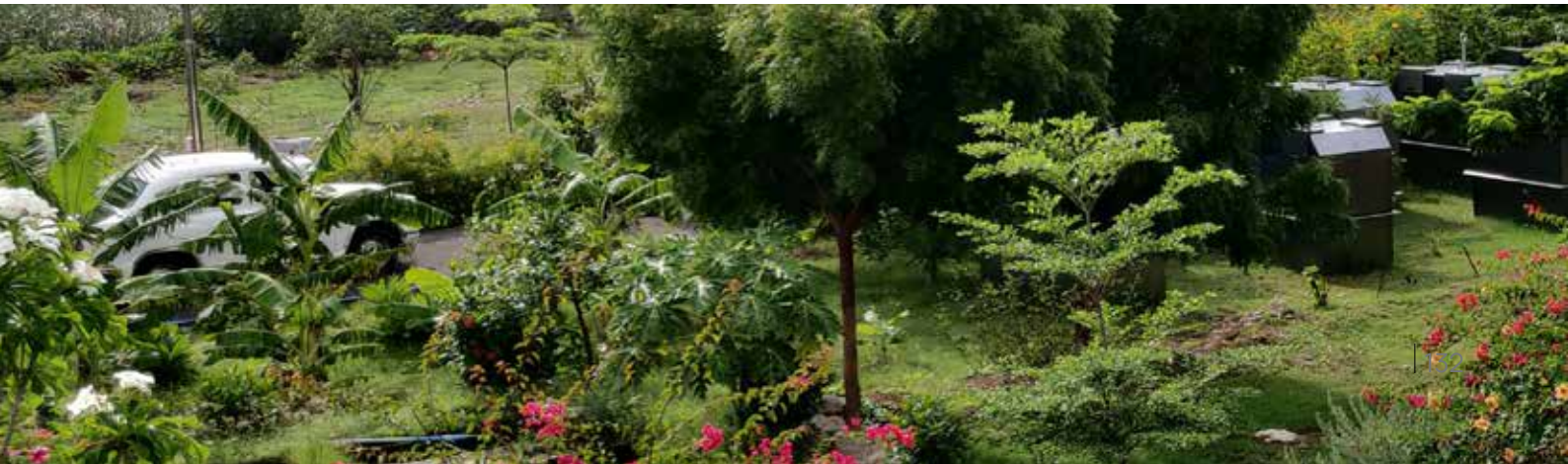
To analyse the vulnerability of government and private The vulnerability of various locations in Tirunelveli city to extreme heat and urban flooding risks were identified by analysing the locations facing the climate risks and wards with high number of issues in urban service delivery as they directly impact the livelihood of the population during climate disasters. The urban systems for which the vulnerability to climate hazards were analysed include water supply, wastewater management, SWM and transport. A composite map highlighting criticality of wards affected by climate hazards and fragile urban systems is shown in Figure 5.16.

Wards 3 and 12 (3.46% of the population) are critical wards with 4 urban systems threatened by riverine and urban flooding and are exposed to heat stress due to dense development. Nine Wards (5, 7, 25, 30, 40, 41, 42, 52 and 55) are highly vulnerable wards with three fragile urban systems, impacting 14.33% of the city population. Criticality of wards and populations impacted due to climate hazards and fragile urban systems is shown in Table 5.6. It is important to prioritise these wards to implement targeted climate actions as suggested in Chapter 8 to enhance their climate resilience.

Table 5.8: Vulnerable Wards and Population Impacted by Climate Hazards

Likelihood (a) Criticality	Ward numbers along with fragile urban systems (Note: WS – Water Supply; WW – Wastewater; SWM – Solid Waste Management; T – Transport) Consequence (b)	Population impacted	Total population impacted with respect to the total population (%)	Slum population impacted	Slum population impacted with respect to the total slum population (%)
Extreme (Critical wards with four and more urban fragile systems)	Ward 3 (WS, WW, SW, TT), Ward 12 (WS, WW, SW, TT)	19,173	3.46	513	0.69
High (Critical wards with three urban fragile systems)	Ward 5 (WS, SW, TT), Ward 7 (WS, WW, SW), Ward 25 (WW, SW, TT), Ward 30 (WS, SW, TT), Ward 40 (WS, WW, SW), Ward 41 (WS, WW, SW), Ward 42 (WS, WW, SW), Ward 52 (WS, WW, SW), Ward 55 (WS, WW, SW)	79,447	14.33	11,027	14.85

Likelihood (a) Criticality	Ward numbers along with fragile urban systems (Note: WS – Water Supply; WW – Wastewater; SWM – Solid Waste Management; T – Transport) Consequence (b)	Population impacted	Total population impacted with respect to the total population (%)	Slum population impacted	Slum population impacted with respect to the total slum population (%)
Moderate (Critical wards with up to two urban fragile systems)	Ward 6 (WS), Ward 11 (WS), Ward 20 (SW), Ward 21 (WW), Ward 23 (TT), Ward 24 (SW), Ward 27 (TT), Ward 29 (WS), Ward 32 (WS), Ward 35 (WS), Ward 36 (WS), Ward 37 (WS), Ward 38 (WS), Ward 39 (WS), Ward 45 (SW), Ward 46 (WS), Ward 49 (SW), Ward 53 (WS), Ward 54 (WS) Ward 10 (WS, SW), Ward 17 (WS, WW), Ward 33 (WS, SW), Ward 43 (WW, SW), Ward 44 (WW, SW), Ward 48 (WS, SW), Ward 50 (WS, SW), Ward 51 (WS, SW)	286,529	51.67	24,147	32.5
Low (Wards without urban fragile systems)	Wards 1, 2, 4, 8, 9, 13, 14, 15, 16, 18, 19, 22, 26, 28, 31, 34, 47	169,373	30.54	18,954	25.52



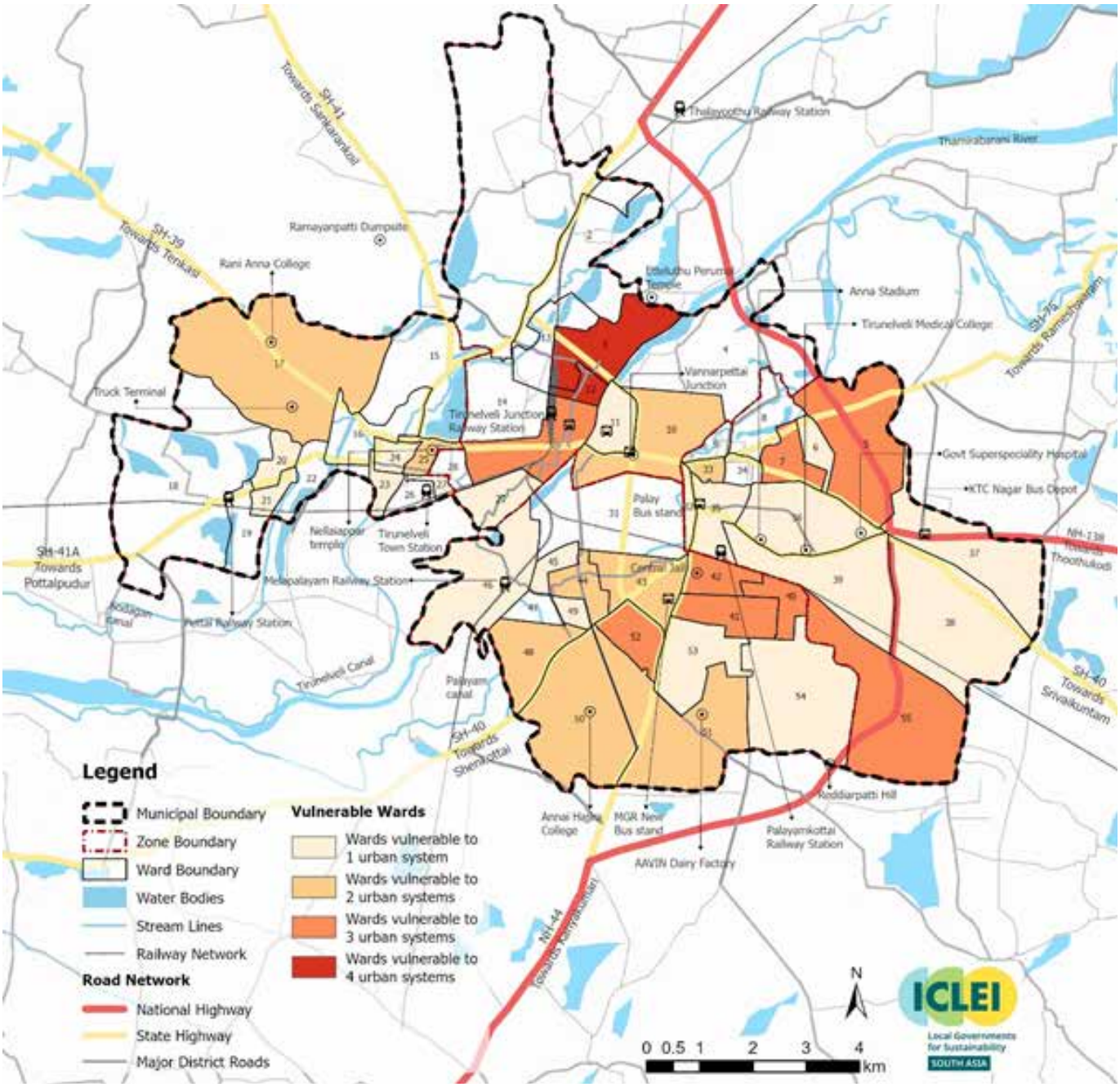


Figure 5.16: Consolidated Vulnerable Hotspots for Tirunelveli Due to Climate Hazards
Source: Prepared by ICLEI South Asia under CapaCITIES Phase II project

5.3.3 Actor Analysis and Adaptive Capacity

The adaptive capacity of various government entities, private sector and population groups in responding to climate disasters and their ability to implement/ support climate resilience actions were assessed including vulnerable groups in urban areas, such as slum dwellers, street vendors, and children. The analysis of various actors and their adaptive capacities are presented in Table 5.7.

Certain demographics, such as the elderly, children, women, people with disabilities, the uneducated, and the economically disadvantaged, face heightened vulnerability to climate-related hazards like heatwaves and floods:

Elderly, children, women, and people with special needs are particularly susceptible to heat-related health issues.

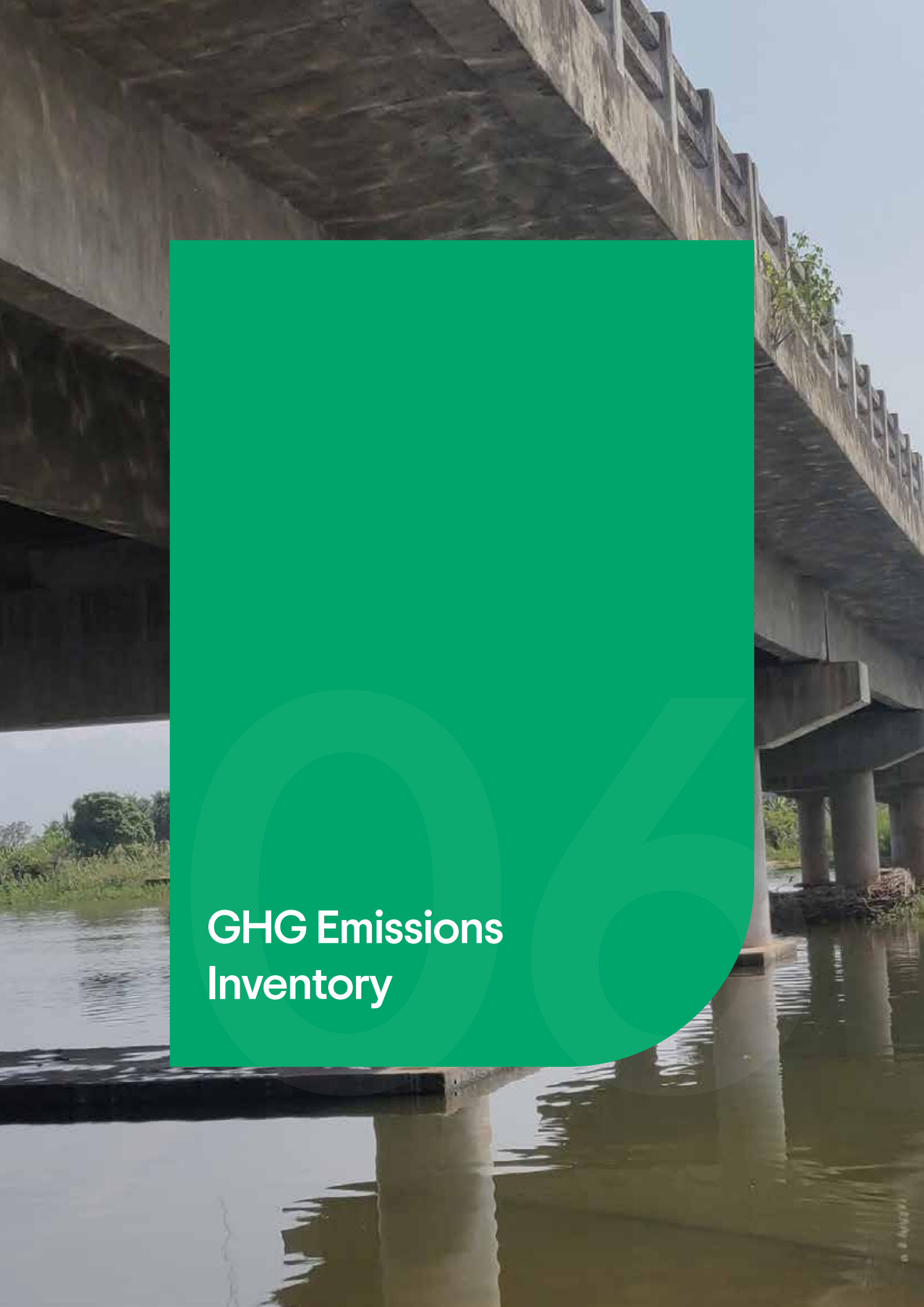
Individuals with disabilities encounter significant challenges in accessing emergency assistance due to insufficient inclusive infrastructure and oversight in disaster management plans, exacerbating their vulnerability.

Limited access to information leaves uneducated individuals more vulnerable, while poor urban dwellers struggle due to inadequate living conditions and healthcare access, especially during floods.

Government departments and the private sector demonstrate high adaptive capacity and can facilitate climate resilient measures in the city. However, marginalised groups such as slum dwellers, the elderly, children, women, people with special needs, and vendors often lack the resources and support needed to cope with climate impacts, and also play a minimal role in supporting climate resilience actions. The CRCAP incorporates initiatives targeting vulnerable population while leveraging the strengths of supporting actors. Government departments and the private sector play pivotal roles in transitioning to a climate resilient and carbon neutral city.

Table 5.9: Adaptive Capacity of Actors in the City

Associated Actors	Capacity to Respond (a)	Resources Available (b)	Capacity to Access Information (c)	Adaptive Capacity Score (a*b*c)	Adaptive Capacity
TCMC	3	2	3	18	High
Regional Transport Office	3	2	3	18	High
Tamil Nadu Pollution Control Board	2	3	2	12	High
Tamil Nadu Public Works Department	2	3	3	18	High
Tamil Nadu Highways Department	2	2	3	12	High
Government health care facilities	3	2	3	18	High
Private hospitals	3	3	2	18	High
NGOs/Charitable institutions	3	2	2	12	High
Traffic Police Department	3	1	3	9	Medium
City Police Department	3	1	3	9	Medium
Tamil Nadu Revenue Department	1	3	2	6	Medium
Tamil Nadu Water and Drainage Board	1	3	2	6	Medium
Pedestrians, cyclists, commuters using two-wheeler	2	2	2	8	Medium
Residents Welfare Associations	3	1	2	6	Medium
Tamil Nadu State Transport Corporation	2	2	2	8	Medium
Contractors/private sector players managing urban infrastructure services for TCMC	3	3	1	9	Medium
Vulnerable people (elderly, children, women, people with special needs)	1	1	1	1	Low
Migrant labour/floating population	1	1	1	1	Low
Uneducated people	2	1	1	2	Low
Slums	1	1	1	1	Low
Rag pickers and people working at dumpsites	1	1	1	1	Low
Street vendors	1	1	1	1	Low



GHG Emissions Inventory

6.1 Introduction

The GHG emissions inventory for Tirunelveli has been prepared for the period 2017-18 to 2021-22 with 2021-22 as the baseline year. The emissions inventory has been prepared following the Global Protocol for Community Scale GHG Emissions (GPC)[1]. This inventory complies with the BASIC level reporting of GPC which covers Scope 1 emissions from stationary energy sources and in-boundary transportation, Scope 2 emissions from consumption of grid supplied electricity and Scope 1 and Scope 3 emissions from waste[2].

The GHG emissions inventory consists of two analyses -

Community-level emissions inventory – includes GHG emissions from energy consumption and emission sources in residential buildings, commercial buildings, institutional/public buildings and facilities, transport, and those resulting from solid waste and domestic wastewater within the municipal boundary. The community-level inventory is useful to establish baseline status of GHG emissions and develop evidence-based mitigation strategies and actions for multi-sectors at the city-scale.

Local government emissions inventory – includes GHG emissions from the consumption of energy in municipal operations and services such as municipal buildings, street lighting, water supply, wastewater treatment, municipal vehicle fleet, and waste management facilities. In Tirunelveli, these services are administered by TCMC, the urban local administrative body of the city.

The community-level energy consumption and GHG emissions data already account for data related to local government operations. For example, the electricity consumption in municipal facilities for water supply, wastewater management, and street lighting is already likely accounted for in the city-wide dataset for commercial and institutional facilities sub-sector, based on relevant electricity customer/end-user categories as prescribed under the electricity distribution and tariff arrangements. Thus, the local government energy consumption and emissions profile is a subset of the community-level profile. Assessing energy use and emissions for municipal operations separately helps city governments take targeted low-carbon action in their municipal infrastructure and urban service delivery. It enables cities to demonstrate leadership in implementing transformative climate efforts in their communities.

6.2 Methodology

The GHGs considered in the GHG emissions inventory are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) gases which account for nearly 99% of global GHG emissions.

The GHG emissions inventory has been reported in terms of emissions of each individual GHG and the total carbon dioxide equivalent (CO2e) emission. To arrive at the CO2e, the global warming potential (GWP) of each gas for a 100-year timeline is factored. The GWP reflects the climate change impact, in terms of the warming effect on the atmosphere, for each GHG with reference to CO2. The GWP values based on the IPCC's Fourth Assessment Report (2007) are presented in Table 6.1.

Table 6.1: Accessibility of government health care facilities for slum dwellers

Gas	Lifetime (Years)	GWP for 100 years
CH4	12	25
N2O	114	298

6.2.1 Emission factors

For estimating GHG emissions from various activities or sources in a city, it is not feasible to carry out a direct physical measurement of GHGs emitted. The common methodology for estimating GHG emissions is through the use of emission factor[3] and the relevant activity

[1] Refer for more information on GPC - https://ghgprotocol.org/ghg-protocol-cities; Accessed 24 January 2024.

[2] Scope 1 emissions include GHG emissions from sources located within the city boundary; Scope 2 emissions include GHG emissions from the use of grid-supplied electricity, heat, steam, and/or cooling within the city boundary; Scope 3 emissions include all other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.

[3] The emission factor for a particular activity is dependent on the energy use and direct GHG emissions resulting from the activity. As a result of this dependence, emission factors tend to vary over locations and for different technologies. For example, the emission factor per kWh of electricity used would vary over countries or regions due to the varying energy mix, characteristics of fuel used, and the efficiency of electricity generation. The emission factor per km travelled would vary depending on the fuel characteristics, the engine characteristics for the vehicle, and the driving and traffic patterns prevalent. For accurately estimating a GHG emissions inventory, it is important to use the emission factor best suited to the location.

data[4] to estimate the emissions.

GHGA = EFA × DA
Where,
GHGA = GHG emissions resulting from activity A
EFA = emission factor for activity A
DA = data for activity A

For Tirunelveli's GHG inventory, relevant emission factors as available in the HEAT+ tool, developed by ICLEI, have been used to arrive at GHG emissions from different sources and activities.

For emissions from solid waste disposal in the city, the First Order Decay (FOD) methodology has been employed[5]. Since the GHG emissions from solid waste disposal continue for several years even after disposal, the FOD methodology assumes that the degradable organic component (DOC) in waste decays slowly over time, during which emissions are released. It therefore helps to account for GHG emissions that are released as waste decomposes over longer periods.

To estimate on-road transport emissions, the fuel sales method has been used. This method calculates on-road transport emissions by considering the total fuel sold within city limits. This approach regards fuel sold as an indicator of transport activity within the city[6].

Emissions from rail transit within the city boundary have been accounted using the distance based method, based on passenger-kms travelled. Estimation of passenger-kms travelled relies on two key indicators: the number of passengers carried and the average distance travelled by each passenger. To account for in-boundary emissions, only the length of rail track within the city boundary has been considered for the calculations.

6.2.2 Emission sources excluded and included elsewhere

As noted earlier, the GHG emissions inventory is compliant with the requirements of the GPC BASIC reporting framework. Emission sources that are excluded from the inventory and categorised elsewhere are as follows:

- Emissions from agriculture, forestry, and land-use change (AFOLU); and industrial processes and product use (IPPU) are excluded from the inventory as they fall beyond the scope of the GPC BASIC framework.
- Emissions resulting from transmission and distribution losses linked to grid-supplied electricity are excluded from the inventory as they fall beyond the scope of the GPC BASIC framework.
- Tirunelveli's aviation emissions are transboundary in nature. The city is not served by an airport and the citizens depend on the regional airport located near Tuticorin city at a distance of 40 km that provides connecting services to major international airports in the region such as to Chennai, Bengaluru, and Coimbatore. Therefore, aviation emissions are not considered as part of GHG accounting for Tirunelveli's transport sector.
- Due to a lack of disaggregated data on fuel consumption for off-road transport within the city, emissions from such sources are included in the emissions reported under on-road transportation.

6.2.3 Harmonized Emission Analysis Tool plus (HEAT+)

ICLEI's HEAT+ is an online emissions accounting software package that helps local governments account for GHG emissions and develop a comprehensive energy and GHG emissions inventory of their cities. The tool helps them make informed climate action decisions and was used to assist with the accounting of Tirunelveli's GHG emissions inventory. The HEAT+ tool incorporates the latest technical findings (IPCC, 2006) and international reporting requirements and standards outlined in the GPC. HEAT+ contains numerous country specific emission factors and energy densities for a wide range of fuels, combustion technologies, and waste types. It uses these values to calculate the GHG emissions resulting from electricity use, fuel consumption, and waste decomposition. HEAT+ is GPC compliant and includes a local government module to reflect GHG emissions limited to municipal operations.

The HEAT+ tool supports cities in the implementation of ICLEI's Climate Action methodologies, including the 'Net Zero ClimateResilientCities (CRC)' methodology.

[4] Activity data is a quantitative measure of a level of activity that results in GHG emissions during the given period of time.

[5] To learn more about the FOD methodology for accounting GHG emission from MSW, refer Section 8.3 Calculating emissions from solid waste disposal, Global Protocol for Community-Scale Greenhouse Gas Emission Inventories. Available at https://ghgprotocol.org/sites/default/files/ghgp/standards/GHGP_GPC_0.pdf.

[6] To learn more about fuel sales approach, refer GPC - https://ghgprotocol.org/ghg-protocol-cities; Accessed 18 October 2023.

Through its extensive database of IPCC and country-specific emissions coefficient data sets, and ability to generate analyses and various built-in reports, HEAT+ provides a robust tool to prepare city specific GHG emissions inventories to support comprehensive climate action plans.Due to a lack of disaggregated data on fuel consumption for off-road transport within the city, emissions from such sources are included in the emissions reported under on-road transportation.

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6.2.4 Data Sources and Collection

The baseline year for Tirunelveli's GHG emissions inventory is the financial year 2021-22 (i.e., April 2021 - March 2022). Relevant data for the analysis and estimation was collected for a five-year period preceding the baseline year i.e., 2017-18 onwards. A full GHG emissions inventory includes emissions from energy, waste, and AFOLU sectors. However, due to limited resources and data constraints, the direct emissions from AFOLU sectors were not included.

ICLEI South Asia and TCMC officials engaged with various government agencies, local and sub-national stakeholders, through official letters and meetings to source the relevant energy consumption data focusing on the primary emission sources within the municipal jurisdiction. The supply and demand-side data were collected and analysed. The various sources of energy and other relevant data used in the report are elaborated in Table 6.2.

6.2.5 Assumptions for Activity Data

The activity data for certain sectors and sub-sectors is based on the following assumptions:

The electricity consumption data for inventory does not include full High Tension (HT) consumption data for the inventory period due to difficulties in extracting HT billing data by TANGEDCO officials from their billing management system. As a reference, the HT consumption data for around 50 HT consumers in the city (no significant change during inventory period) for limited time period was shared which was then used to extrapolate and arrive at HT consumption data for 5 years following the trend of Low Tension (LT) consumption.

Municipal consumption data is based on the sector-wise expense on electricity and fuel consumption reported in the income expenditure statement of Tirunelveli city as direct records of municipal consumption are not available in a consolidated form with the city.

Table 6.2: Footpaths in Tirunelveli

Fuel Type	Sector	Source of Data
Electricity	Residential, Commercial/Institutional Facilities; Manufacturing Industries and Construction; Agriculture, Forestry and Fishing Activities (i.e. mainly agriculture)	Tamil Nadu Electricity Board (TNEB)
	Municipal Buildings, Water Supply, Wastewater Management, Street Lighting	TCMC
Diesel and Petrol	Community Transport, Commercial/Institutional facilities, Manufacturing Industries and Construction	IOCL (IOCL is state coordinator for all oil & petroleum companies)
	Municipal Vehicles	TCMC
LPG	Residential, Commercial/Institutional Facilities, Manufacturing Industries and Construction, Auto LPG – Community Transport	IOCL
Solid Waste Management		TCMC
Wastewater management		TCMC
Rail		Southern Railway Office, Tirunelveli Railway Junction

6.3 GHG Emissions Inventory

6.3.1 Community Level Energy Consumption and GHG Emissions in Tirunelveli City (2021-22)

Table 6.3: Key indicators – city-scale energy consumption and GHG emissions (2021-22)

Total Energy Use	6.00 million GJ
Total GHG Emissions	0.73 million tCO2e
Per Capita Energy Use	10.83 GJ
Per Capita GHG Emissions	1.32 tCO2e

Tirunelveli city's total energy consumption in 2021-22 is 6,004,395 GJ and the per capita energy consumption is 10.83 GJ. The GHG emissions contribution by Tirunelveli city in the baseline year is 729,704 tCO2e and the per-capita GHG emissions is 1.32 tCO2e.

Table 6.4: Community level sector-wise energy consumption and GHG emissions (2021-22)

Sector/Sub-Sector	Energy Use (GJ)	GHG Emissions (tCO2e)
Stationary Energy	3,416,555	467,258
Residential Buildings	2,226,359	302,959
Commercial and Institutional Buildings/ Facilities	612,583	111,761
Manufacturing Industries and Construction (i.e., Industrial Sector)	577,037	52,424
Agriculture, Forestry, and Fishing Activities (i.e., mainly Agriculture)	576	114
Transportation	2,587,840	194,325
On-Road	2,587,840	1,87,296
Rail	--	7,029
Waste	--	68,122
Solid Waste	--	23,889
Domestic Wastewater	--	44,233
Total	6,004,395	729,704

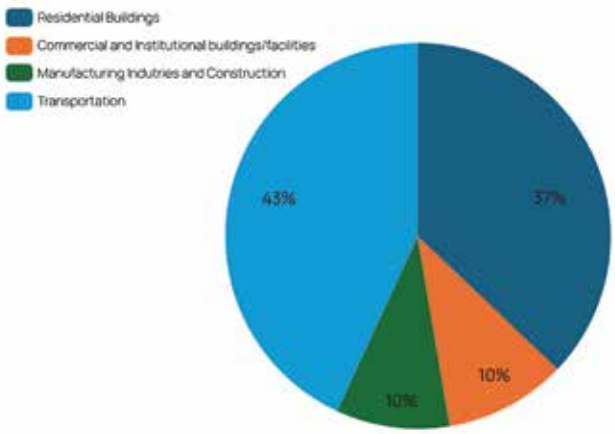


Figure 6.1: Sector-wise share of energy consumption, 2021-22

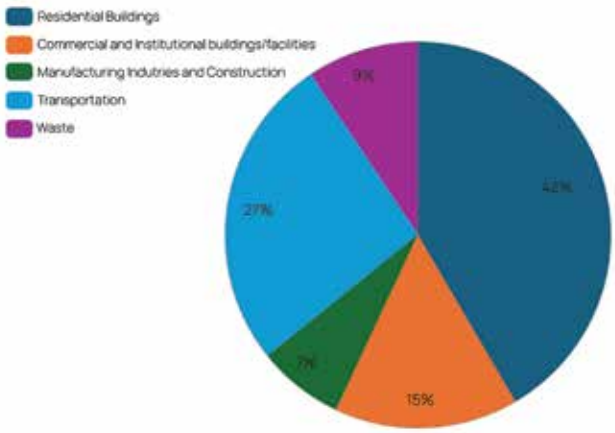


Figure 6.2: Sector-wise share of GHG emissions, 2021-22

6.3.2 Trend of Community Level Energy Consumption and GHG Emissions in Tirunelveli City

Energy Consumption

Energy intensive sectors: Transport (43%), Residential Buildings (37%), Commercial and Institutional Buildings/Facilities (10%)

Energy consumption growth (2017-18 to 2021-22): 8.5% increase at 2.1% annually

GHG Emissions

Sectors with significant GHG emissions: Residential Buildings (42%), Transport (27%), and Commercial and Institutional Buildings/Facilities (15%)

GHG emissions growth (2017-18 to 2021-22): 7.9% increase at 1.96% annually

Trend of Energy Consumption & GHG Emissions from 2017-18 to 2021-22

The growing sectoral energy consumption and GHG emissions from 2017-18 witness negative growth in 2020-21 for all sectors except residential buildings sector due to the impact of COVID-19 lockdowns (Figure 3 & Figure 4).

The annual average growth rate of GHG emissions during the inventory period is observed to be highest in the Residential Buildings sector (4.5%), followed by Transport (3.2%), and Waste (2.4%).

Post COVID-19 restrictions in 2020-21, the industrial and transport emissions increased significantly by 60% and 37% respectively in 2021-22.

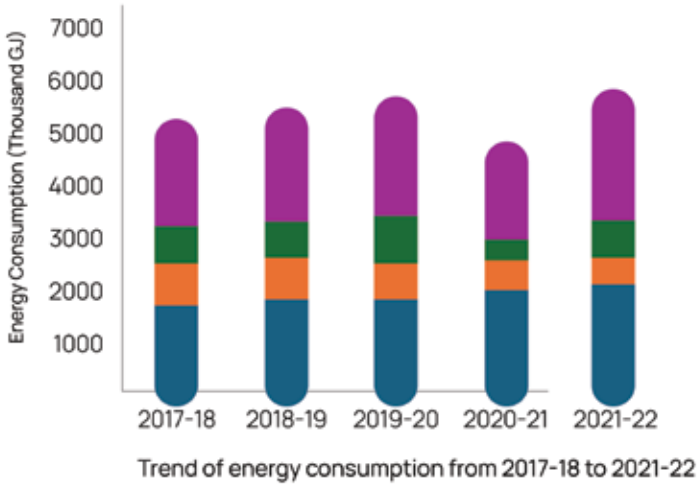


Figure 6.3: Trend of energy consumption from 2017-18 to 2021-229

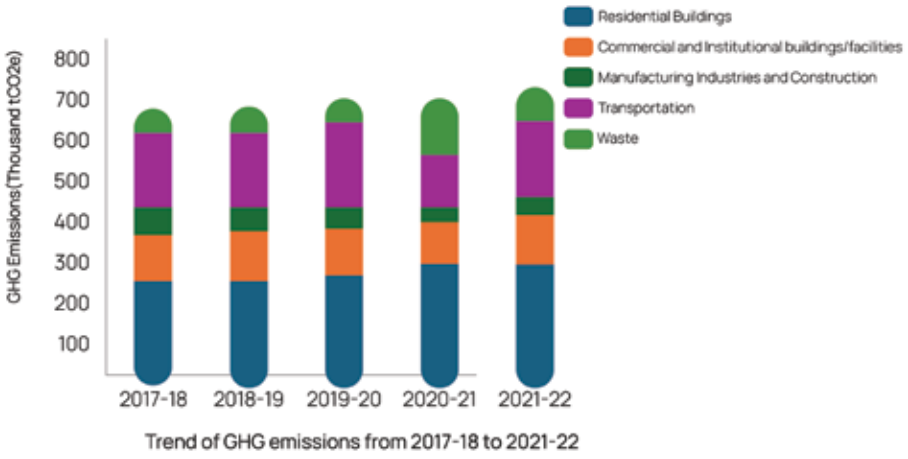


Figure 6.4: Trend of GHG emissions from 2017-18 to 2021-2210

6.3.3 Energy Consumption and GHG Emissions by Energy Source

Table 6.5: Energy consumption and GHG emissions by energy source (2021-22)

Fuel/Energy Source	Energy Consumption by Source Category (GJ)	GHG Emissions (tCO2e)
Diesel	2,021,697	150,321
Petrol	1,066,572	74,184
LPG	1,086,497	68,618
Kerosene	15,445	1,114
Indirect Electricity	1,814,184	360,317
Total	6,004,395	654,554

Predominant energy sources: Diesel (33.7%), Electricity (30.2%), LPG (18.1%), & Petrol (17.8%)
Energy sources with significant GHG emissions: Electricity (55.0%), Diesel (23.0%), and Petrol (11.3%)

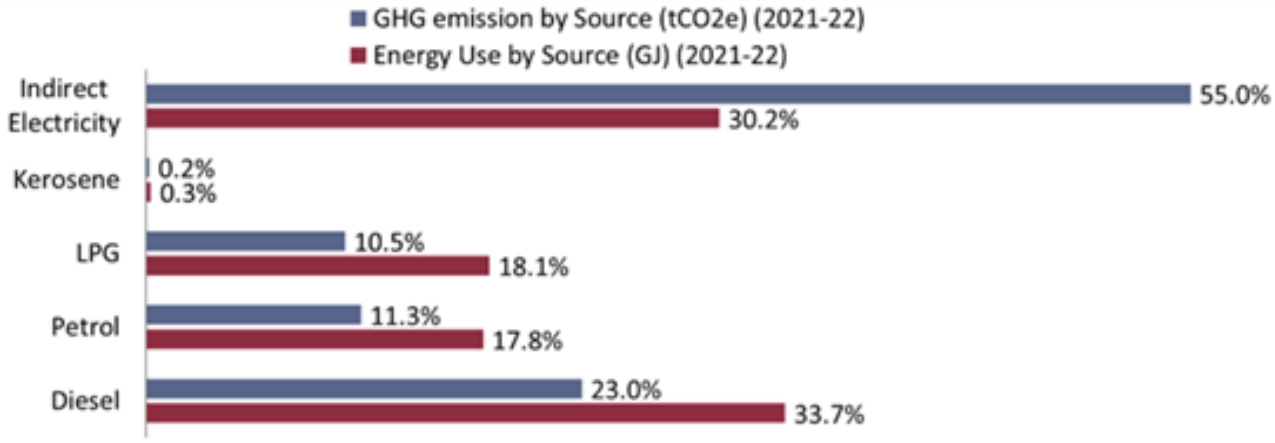


Figure 6.5: Energy consumption and GHG emissions by source in 2021-22

6.3.4 Sectoral Insights and Trends of Energy Consumption and GHG Emissions

6.3.4.1 Sectoral Electricity Consumption and GHG Emissions

Total electricity consumption in 2021-22: 503.9 million kWh

Per capita electricity consumption: 908.8 kWh

GHG emissions from electricity consumption in 2021-22: 360,317 tCO2e

Growth of electricity consumption (2017-18 to 2021-22): 16.6% increase at 4.15% annually

Growth of GHG emissions from electricity consumption (2017-18 to 2021-22): 10.6% increase at 2.64% annually

Sectoral electricity consumption and GHG emissions: Residential Buildings (66%), Commercial and Institutional Buildings/Facilities (30%), Manufacturing Industries and Construction (4%)

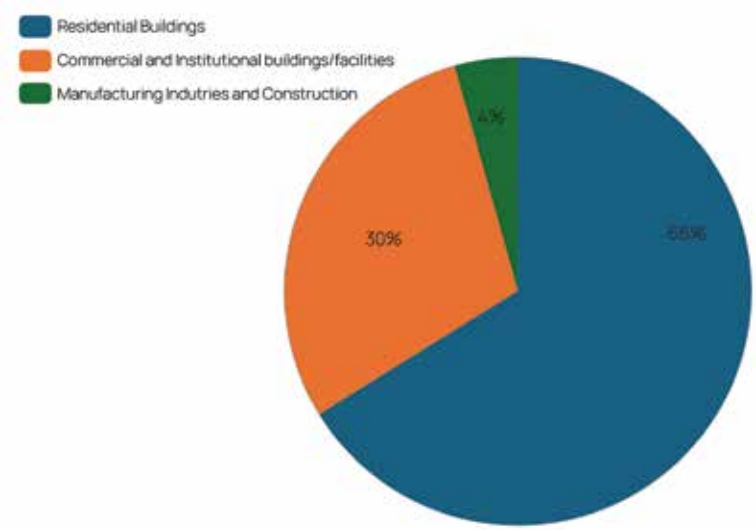


Figure 6.6: Sector-wise GHG emissions from electricity consumption in 2021-22

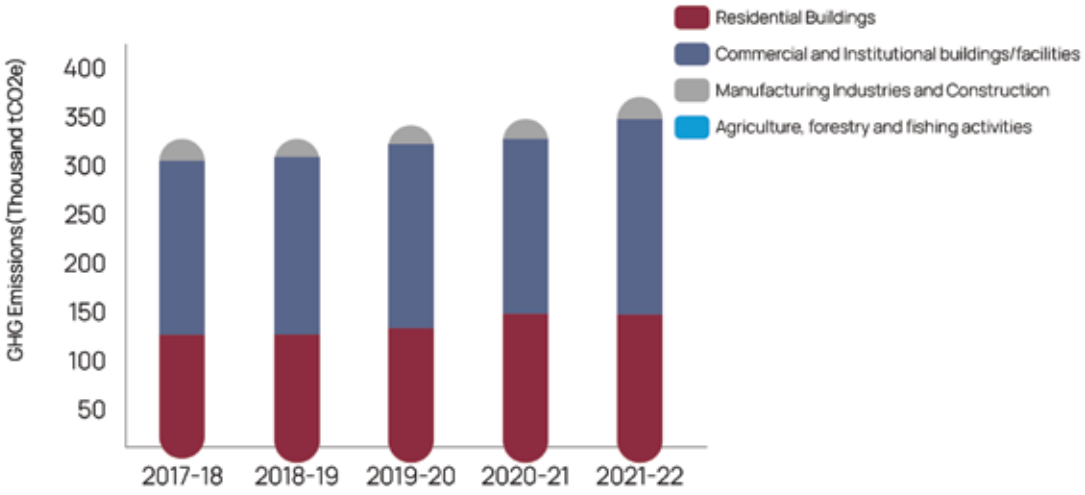


Figure 6.7: Trend of GHG emissions from electricity consumption, 2017-18 to 2021-22

6.3.4.2 GHG Emissions from Stationary Fuel Consumption

Sectoral share of stationary fuel consumption: Residential Buildings (64%), Manufacturing Industries and Construction (5%), Commercial and Institutional Buildings/Facilities (31%)

Sectors with significant GHG emissions: Residential Buildings (61%), Manufacturing Industries and Construction (35%), Commercial and Institutional Buildings/Facilities (4%)

Trend of GHG emissions from stationary fuel consumption (2017-18 to 2021-22):

From 2017-18 to 2019-20, GHG emissions from stationary fuel consumption increased by 6.78% but the overall fuel consumption decreased significantly in 2020-21 except in case of residential sector due to COVID-19 impacts.

GHG emissions witnessed a decline of 8.0% at 2.0% annually during the inventory period, but the residential sector emissions increased significantly by 18.8% at an annual average growth rate of 4.7%.

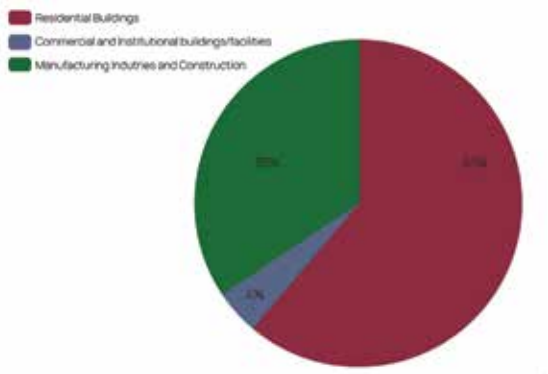


Figure 6.8: Sector share in GHG emissions from stationary fuel consumption (2021-22)

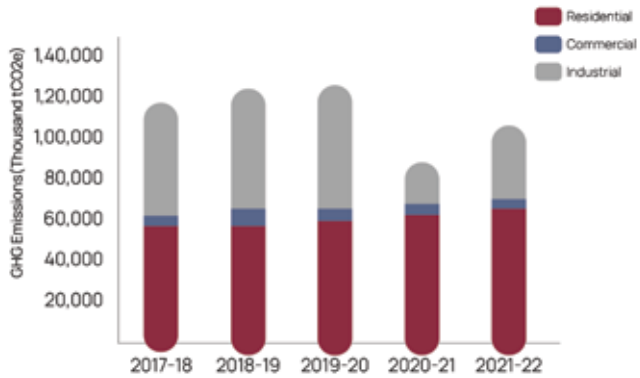


Figure 6.9: Trend of GHG emissions from stationary fuel consumption (2017-18 to 2021-22)

Table 6.6: Energy consumption and GHG emissions from stationary fuel consumption (2021-22

Fuel/Energy Source	Energy Consumption by Source Category (GJ)	GHG Emissions (tCO2e)
Residential Buildings	1,028,819	65,114
Commercial and Institutional Buildings/ Facilities	73,123	4,618
Manufacturing Industries and Construction	500,429	37,209
Total	1,602,371	106,941

a. Stationary Energy Use in Residential Buildings

Energy consumption from stationary fuel consumption (2021-22): 1,028,819 GJ

GHG emissions from stationary fuel consumption (2021-22): 65,114 tCO2e

Trend of energy consumption from stationary fuel (2017-18 to 2021-22): 19.8% increase at 4.95% annually

Trend of fuel consumption in residential sector (2017-18 to 2021-22):

LPG: 27.5% increase at 6.87% annually

Kerosene: 76.0% decline at 19.0% annually

Trend of GHG emissions from stationary fuel (2017-18 to 2021-22): 18.8% increase at 4.7% annually

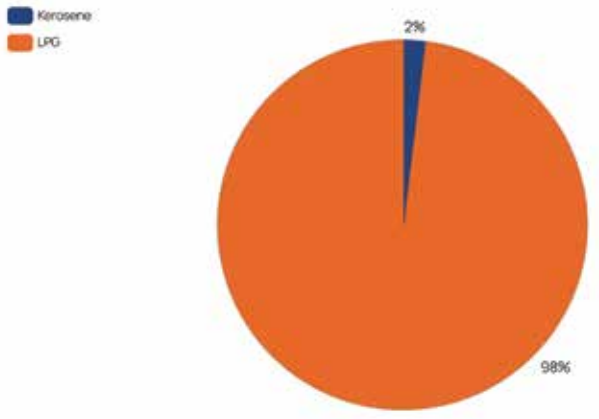


Figure 6.10: Stationary fuel consumption in residential buildings in 2021-22

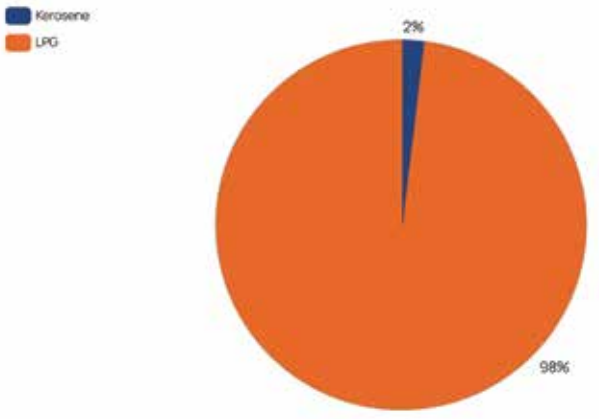


Figure 6.11: GHG emissions from stationary fuel consumption in residential buildings in 2021-22

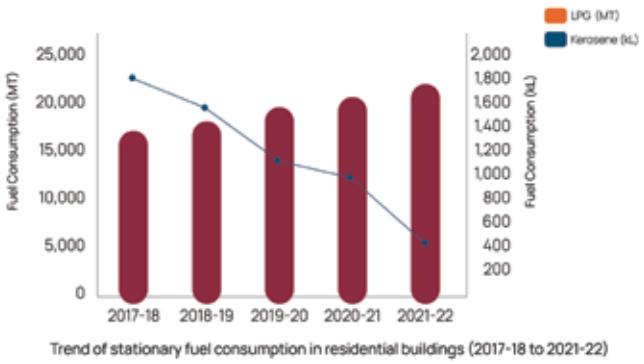


Figure 6.12: Trend of stationary fuel consumption in residential buildings (2017-18 to 2021-22)

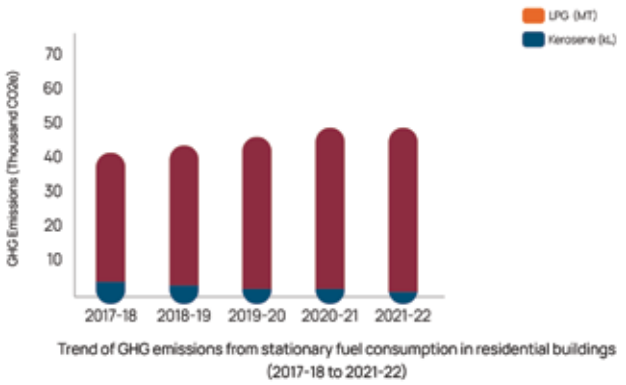


Figure 6.13: Trend of GHG emissions from stationary fuel consumption in residential buildings (2017-18 to 2021-22)

b. Stationary Energy Use in Commercial and Institutional Buildings/Facilities

Energy consumption from stationary fuel consumption (2021-22): 73,123 GJ

GHG emissions from stationary fuel consumption (2021-22): 4,618 tCO2e

Trend of Fuel Consumption (2017-18 to 2021-22):

LPG: 29% decline at 7.2% annually

Trend of Energy consumption and GHG emissions (2017-18 to 2021-22): 29% decline at 7.2% annually

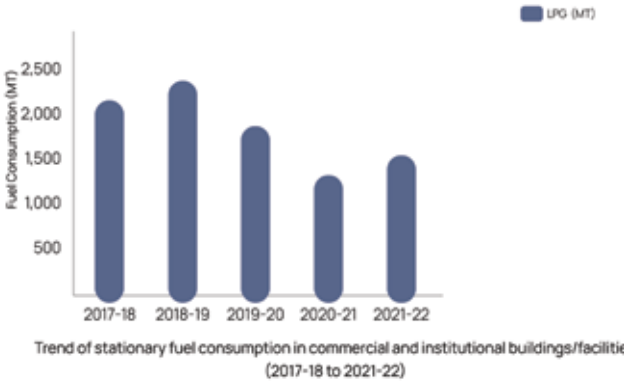


Figure 6.14: Trend of stationary fuel consumption in commercial and institutional buildings/facilities (2017-18 to 2021-22)

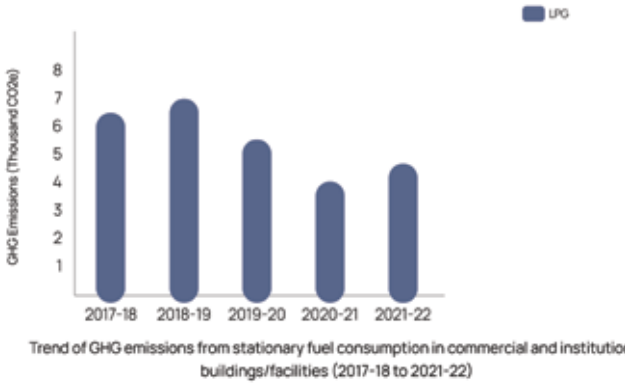


Figure 6.15: Trend of GHG emissions from stationary fuel consumption in commercial and institutional buildings/ facilities (2017-18 to 2021-22)

c. Stationary Energy Use in Manufacturing Industries and Construction

Energy consumption from stationary fuel consumption (2021-22): 500,429 GJ

GHG emissions from stationary fuel consumption (2021-22): 37,209 tCO2e

Trend of fuel consumption and GHG Emissions in Manufacturing Industries and Construction (2017-18 to 2021-22):

Diesel: 32.2% decline at 8.1% annually

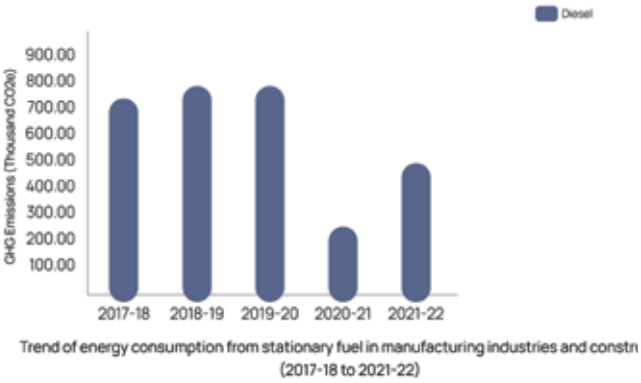


Figure 6.16: Trend of energy consumption from stationary fuel in manufacturing industries and construction (2017-18 to 2021-22)

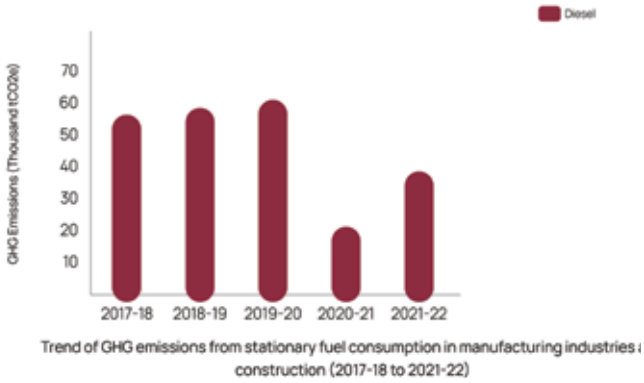


Figure 6.17: Trend of GHG emissions from stationary fuel consumption in manufacturing industries and construction (2017-18 to 2021-22)

6.3.4.3 GHG Emissions from Transportation

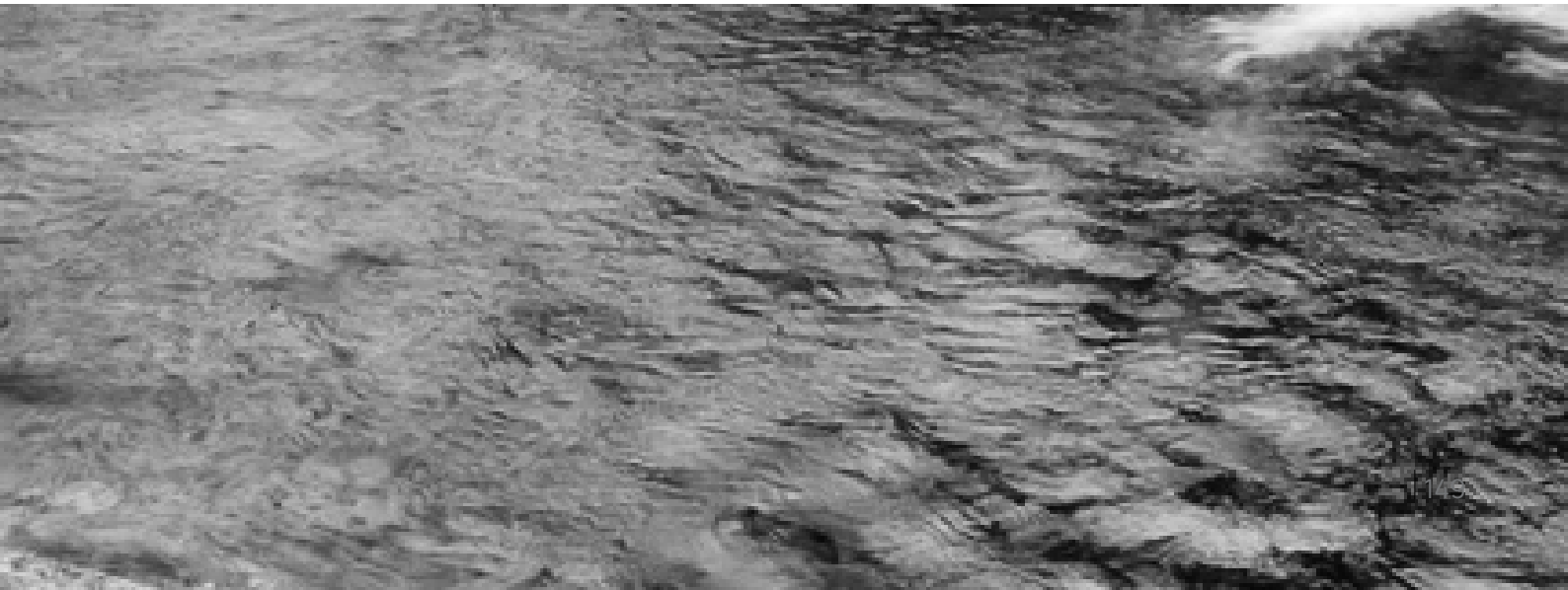
In Tirunelveli, the transport sector mainly consists of road and rail transportation.

GHG emissions share by mode: On-road Transport (96.4%) and Rail (3.6%)

Trend of GHG emissions (2017-18 to 2021-22): 12.8% decline at 3.2% annually

Table 6.7: GHG emissions from transportation sector in Tirunelveli

On-Road	GHG Emissions (tCO2e)				
	2017-18	2018-19	2019-20	2020-21	2021-22
On-Road	165,226	164,277	166,585	138,198	187,296
Rail	7,029	7,029	7,029	3,466	7,029
Total	172,255	171,305	173,614	141,665	194,325



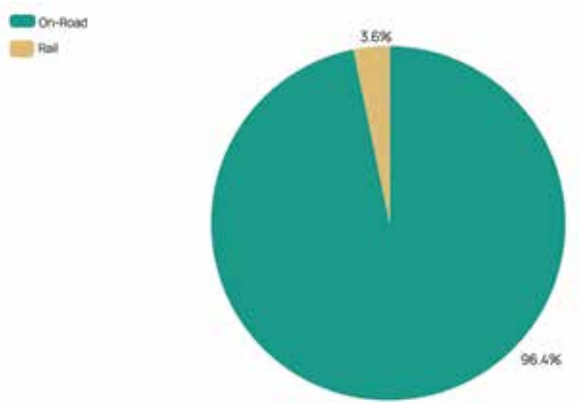


Figure 6.18: GHG emissions by different modes of transportation in Tirunelveli (2021-22)

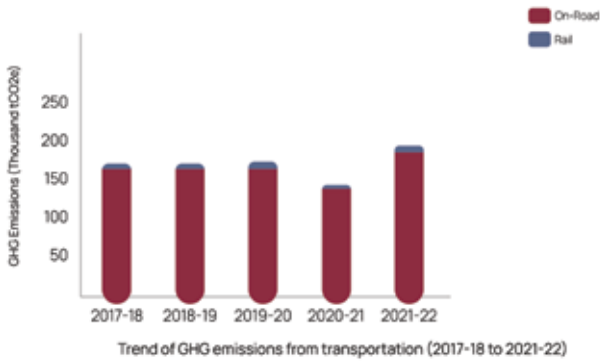


Figure 6.19: Trend of GHG emissions from stationary fuel consumption in manufacturing industries and construction (2017-18 to 2021-22)

a. GHG Emissions from Fuel Consumption in On-Road Transport

Energy consumption from On-Road Transport (2021-22): 2,587,840 GJ

GHG emissions from On-Road Transport (2021-22): 187,296 tCO2e

Trend of energy consumption (2017-18 to 2021-22): 13.6% increase at 3.4% annually

Trend of fuel consumption (2017-18 to 2021-22):

Diesel: 7.3% increase at 1.8% annually

Petrol: 24.1% increase at 6.02% annually

Trend of GHG emissions (2017-18 to 2021-22): 13.4% increase at 3.34% annually

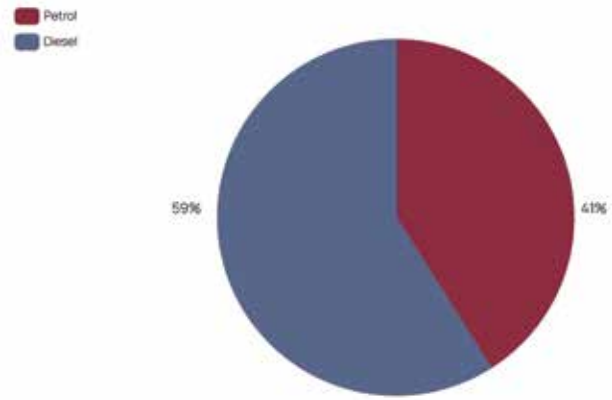


Figure 6.20: Fuel consumption by on-road transportation (2021-22)

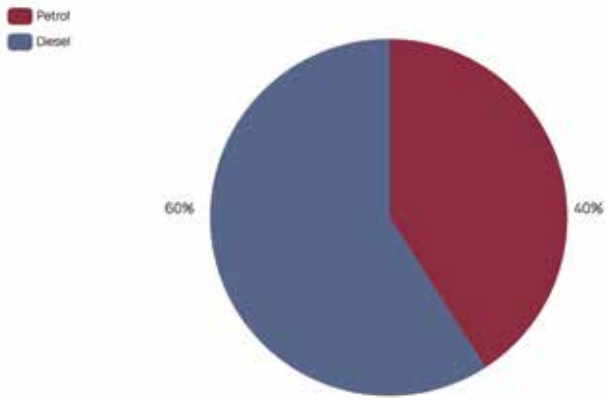


Figure 6.21: GHG emissions from fuel consumption by on-road transportation (2021-22)

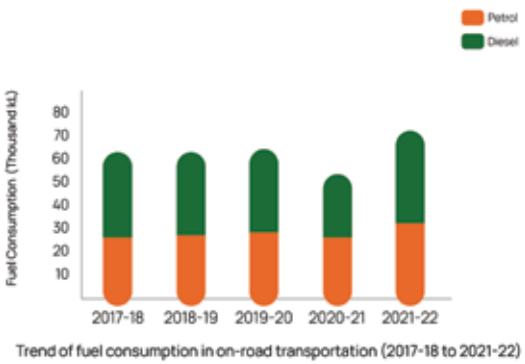


Figure 6.22: Trend of fuel consumption in on-road transportation (2017-18 to 2021-22)

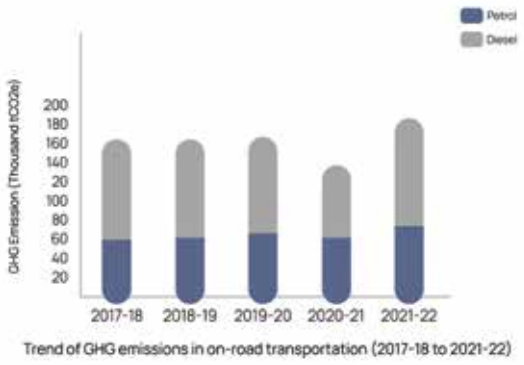


Figure 6.23: Trend of GHG emissions in on-road transportation (2017-18 to 2021-22)

6.3.4.4 GHG Emissions from Waste Sector

GHG emissions from waste sector (2021-22): 68,122 tCO2e

Contribution to GHG emissions: Domestic Wastewater (65%), Solid Waste (35%)

Trend of GHG emissions (2017-18 to 2021-22): 9.5% increase at 2.36% annually

a. GHG Emissions from Solid Waste Management

Solid Waste Scenario:

Waste generation (2021-22): 230 TPD

Waste collection: 90% of generated waste (~207 TPD)

Waste Composition: Food waste (44.18%), Garden Waste (19.59%), Paper (7.14%), Wood & Straw (8.45%), Textiles (1.51%), Disposable Nappies (2.08%) and Rubber (0.34%)

Waste disposed at dumpsite (2021-22): 182 TPD (79.1% of the waste generated)

Waste composted at composting facilities (2021-22): 25 TPD (10.9% of the waste generated)

GHG Emissions from SWM:

GHG emissions from solid waste disposal (2021-22): 22,324 tCO2e

GHG emissions from composting of biological waste (2021-22): 1,565 tCO2e

Trend of GHG emissions from SWM (2017-18 to 2021-22): 36.1% increase at 9.04% annually

While GHG emissions from solid waste disposal at dumpsite increased by 27.5% at an average rate of 6.87%, GHG emissions from composting of biological waste saw a steep increase during the inventory period due to increase in composting capacity of the city. The inventory period saw significant addition in capacity to compost biological waste, with 46 MCCs and 1 central MCC of 20 TPD capacity built during the period.

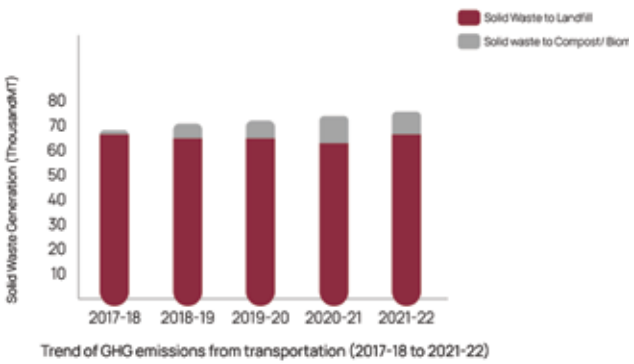


Figure 6.24: Trend of solid waste management (2017-18 to 2021-22)

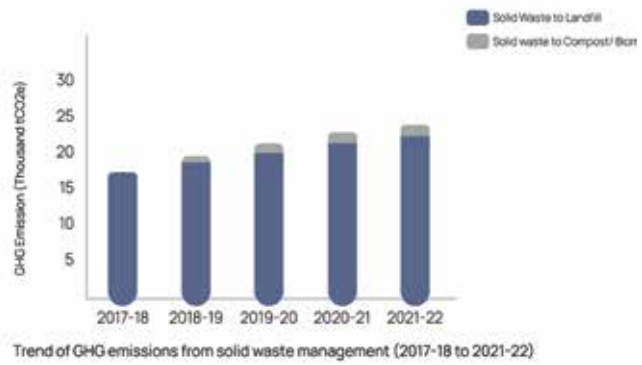


Figure 6.25: Trend of GHG emissions from solid waste management (2017-18 to 2021-22)

b. GHG Emissions from Domestic Wastewater Treatment and Discharge

GHG emissions from domestic wastewater management (2021-22): 44,233 tCO2e

Trend of GHG emissions (2017-18 to 2021-22): 1.02% decline at 0.26% annually

Predominant contributors to GHG emissions: Latrine System (45.4%) and Septic System (35.68%)

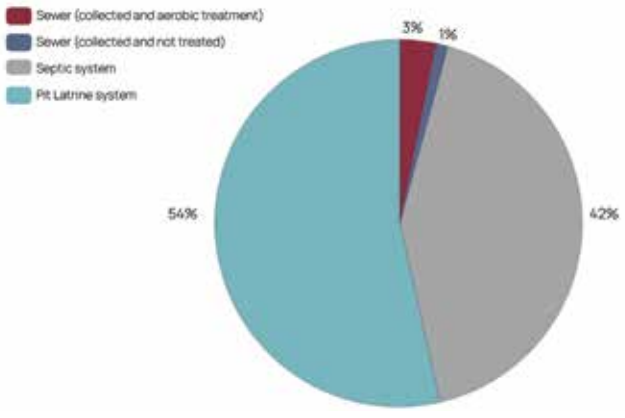


Figure 6.26: GHG emissions by type of discharge/treatment pathway (2021-22)

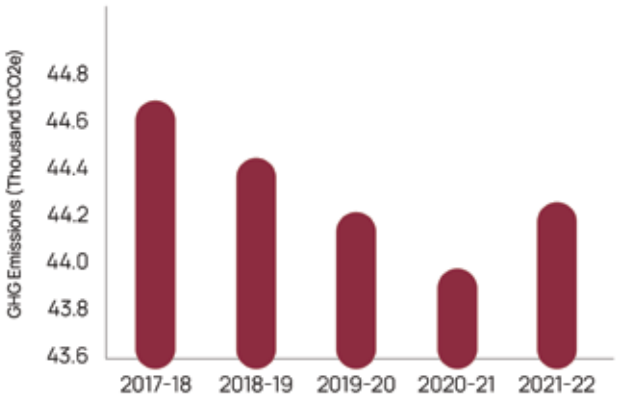


Figure 6.27: Trend of GHG emissions from wastewater management (2017-18 to 2021-22)

6.4 Municipal Operations: Energy Consumption and GHG Emissions

6.4.1 Energy consumption and GHG emissions (2021-22)

Predominant electricity consumers: Water Supply (71%), Street Lighting (16%), and Wastewater Treatment (9%)

Trend of electricity consumption (2017-18 to 2021-22): 10.1% increase at 2.53% annually

Main contributors to GHG emissions: Water Supply (71%), Street Lighting (15%), and Wastewater Treatment (9%)

Trend of GHG emissions (2017-18 to 2021-22): 3.9% increase at 0.97% annually

Table 6.8: Fuel and electricity consumption, and associated GHG emissions from municipal operations (2021-22)

Particulars	2022-23	Benchmark	Unit
Buildings	Diesel: 1.06	1.1	808
Wastewater Treatment	Diesel: 0.79	2.2	1,561
Water Supply	Diesel: 2.38	18.2	12,984
Street Lighting	–	4.0	2,839
Municipal Vehicle Fleet	Diesel: 46.1 Petrol: 2.65	–	137
Total	Diesel: 50.28 Petrol: 2.65	25.4	18,329

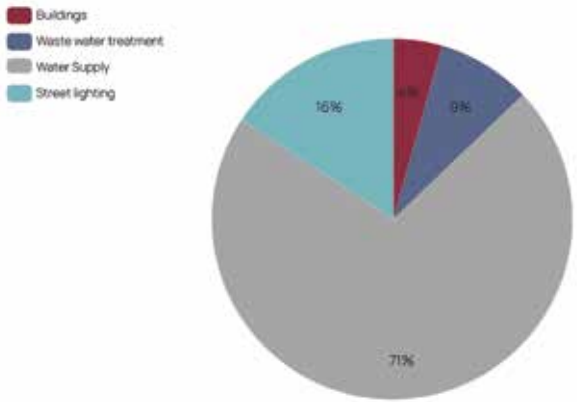


Figure 6.28: Electricity consumption from municipal operations (2021-22)

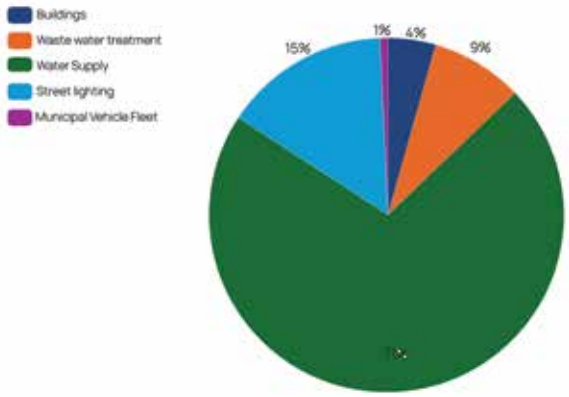


Figure 6.29: GHG emissions from municipal operations (2021-22)

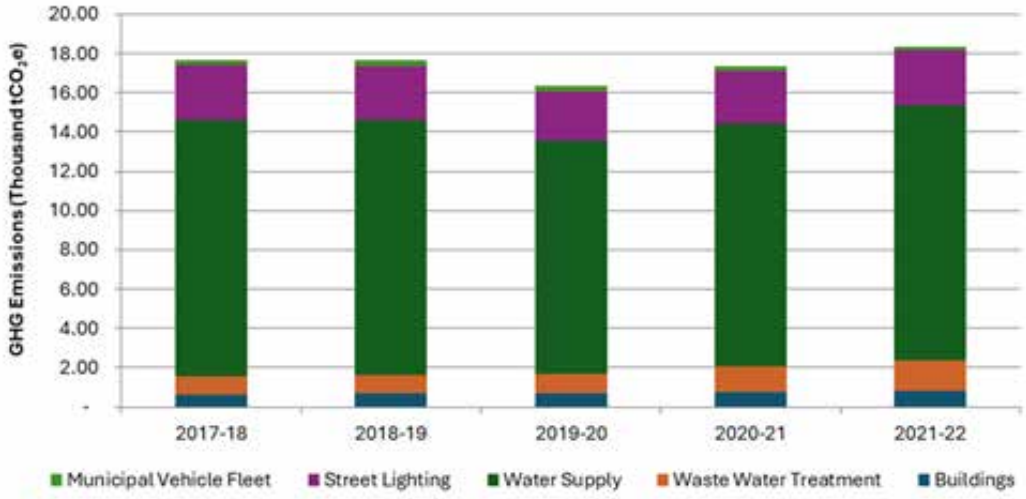
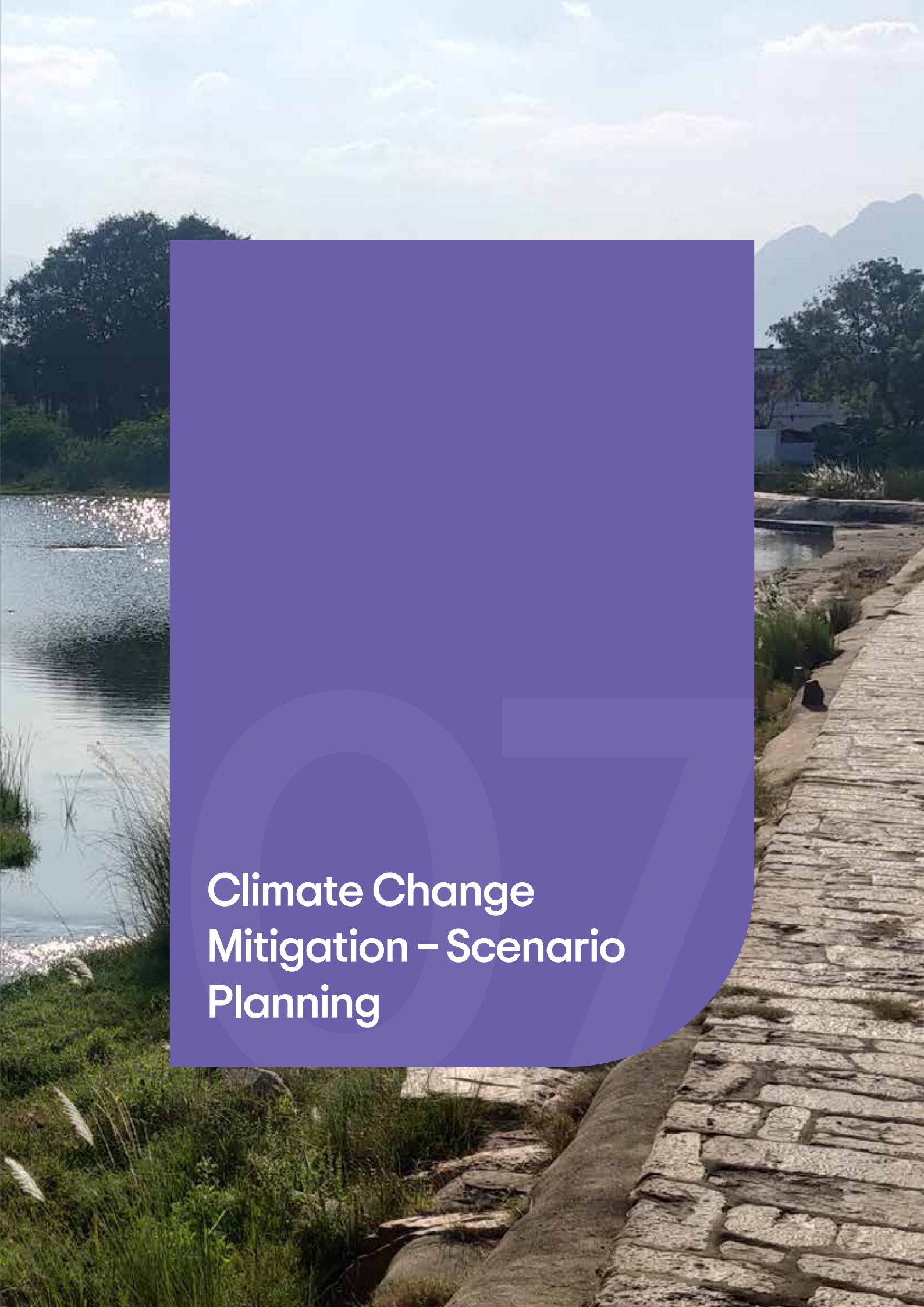


Figure 6.30: Trend of GHG emissions from municipal operations (2017-18 to 2021-22)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Embassy of Switzerland in India
CapaCITIES



Climate Change Mitigation – Scenario Planning

The Net-zero Climate Resilient City Action Plan (CRCAP) of Tirunelveli city strives to bolster the city's resilience to climate change and guide the city in working towards achieving a net-zero emissions status by 2070, aligning with India's national climate ambitions. As a key driver of local climate action, Tirunelveli's Net-zero CRCAP focuses on evaluating the current GHG emissions across various sectors, projecting future GHG emissions based on anticipated socio-economic development, and proposing effective mitigation strategies to meet the city's ambitious climate objectives and targets.

The Tirunelveli Net-zero CRCAP identifies the major sources of GHG emissions and opportunities and recommends various strategies to reduce GHG emissions, including promotion of energy efficiency (EE) in buildings, increased utilisation of renewable energy (RE), adoption of sustainable waste management practices, and promotion of low-carbon transportation alternatives. However, widespread uncertainty over emerging and future technologies and socio-economic development may influence the impact of the GHG emissions mitigation efforts being undertaken now and in the future.

Scenario planning addresses future uncertainties by developing strategies based on multiple potential scenarios with varying outcomes. It is integral to GHG emission forecasting and climate change mitigation planning, serving as a crucial step in mapping different trajectories for future emissions. This process helps determine appropriate emissions reduction strategies, set targets, and estimate the resulting GHG emission levels, thus, steering the city towards its overarching goal of net-zero emissions.

Scenario planning aims to illustrate potential future emissions levels under different scenarios, providing a basis for determining the necessary levels of ambition and climate actions to achieve net-zero goals. The GHG emissions inventory offers insight into emissions from various activities and sources within the city, supporting a comprehensive understanding of the current emissions landscape.

What is the end goal guiding Tirunelveli's GHG emissions reduction strategy?

The target set out in the Scenario Planning exercise is for Tirunelveli to achieve net-zero emissions by 2070, in line with India's national commitment.

Defining net-zero GHG emissions

"Net-zero refers to a state of balance between the quantity of anthropogenic GHG emissions and their anthropogenic removals from the atmosphere."

In case of cities, this implies net-zero GHG emissions rather than net-zero CO_2 emissions, as the former also includes non-CO_2 GHG removals.

The GHG emissions baseline serves as the starting point for scenario planning, which helps establish emissions reduction targets and climate actions. The next step involves projecting business-as-usual (BAU) emissions until 2070, considering growth factors such as economic and population growth rates, urbanisation, and municipal service demand. Subsequently, two emissions reduction scenarios were developed, each featuring a set of locally appropriate strategies and quantifiable targets, to reduce the BAU emissions trajectory and move towards net-zero emissions.

The first scenario, the Progressive Action Scenario, represents an interim pathway with a higher level of ambition for emissions reduction compared to BAU, while being reflective of on-ground efforts, local context, and available resources. The second scenario, the Net-zero Pathway Scenario, outlines an even higher and necessary level of ambition, with targets and strategies required to achieve net-zero emissions. Figure 7.1 illustrates the process followed for scenario planning for future emissions reduction for Tirunelveli.

7.1 Scenarios Identified for GHG Emissions Reduction

Tirunelveli's Net-zero CRCAP identifies two future scenarios, **'Progressive Action'** and **'Net-zero Pathway'** scenarios, which represent three different levels of ambition and targets while defining climate actions that help reduce GHG emissions in the city. In addition to this, BAU emissions projections have been developed to demonstrate the baseline of current and future emissions in the absence of climate change mitigation efforts. These 3 scenarios are briefly defined below and further illustrated by Figure 7.2:

- BAU Scenario: The BAU scenario represents the city's baseline emissions levels in future when no additional measures or interventions are implemented to reduce GHG emissions in the city beyond what is already being implemented. This scenario also serves as the reference point for defining actions and assessing impacts under the other two scenarios.

- **Progressive Action Scenario:** The Progressive Action scenario represents a higher level of GHG emissions reduction resulting from climate actions at the local level in line with the current goals and targets set by the national and state government policies and programs. The existing status of adoption of such national and state policies and programs, local context of the city, unique opportunities, and the capacity of the local government are also reflected in this scenario.
- **Net-zero Pathway Scenario:** The Net-zero Pathway scenario aligns with the ambition and commitment of Government of India (GoI) to achieve net-zero emissions by 2070. This scenario is reflective of the ambitious targets and actions the city must demonstrate beyond existing plans and its capacity to be able to transition towards a net-zero GHG emissions city by 2070.

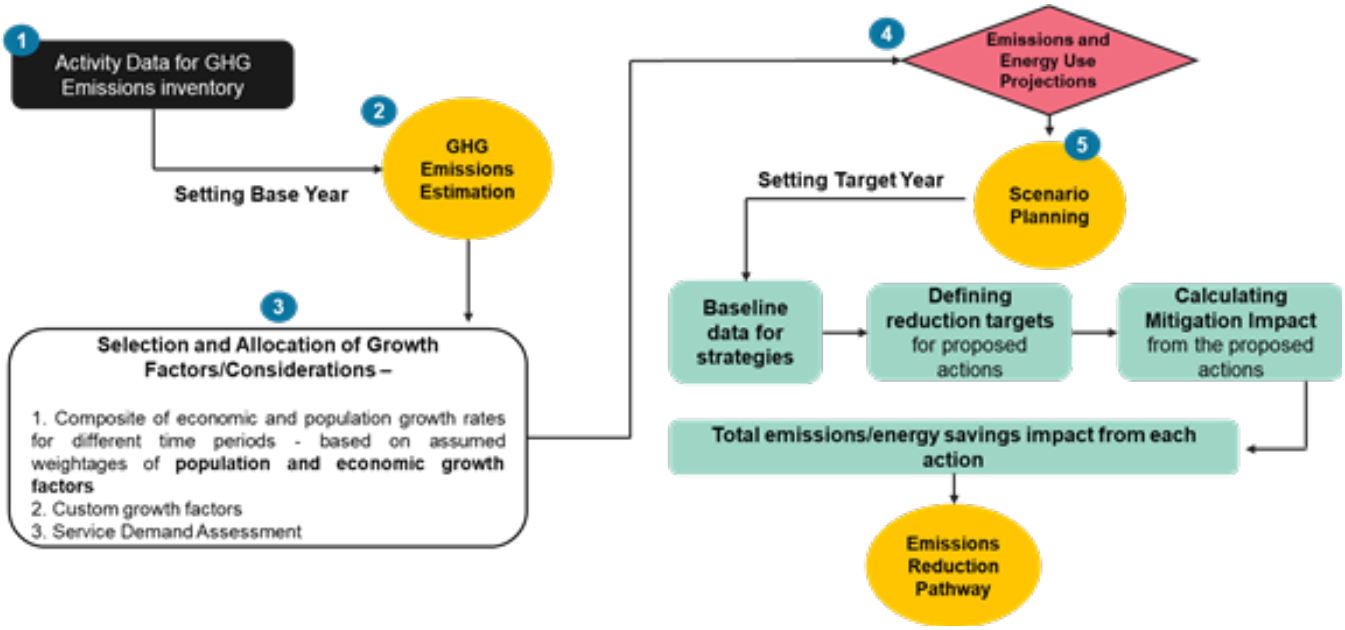


Figure 7.1: ICLEI's Net-Zero Scenario Planning Process

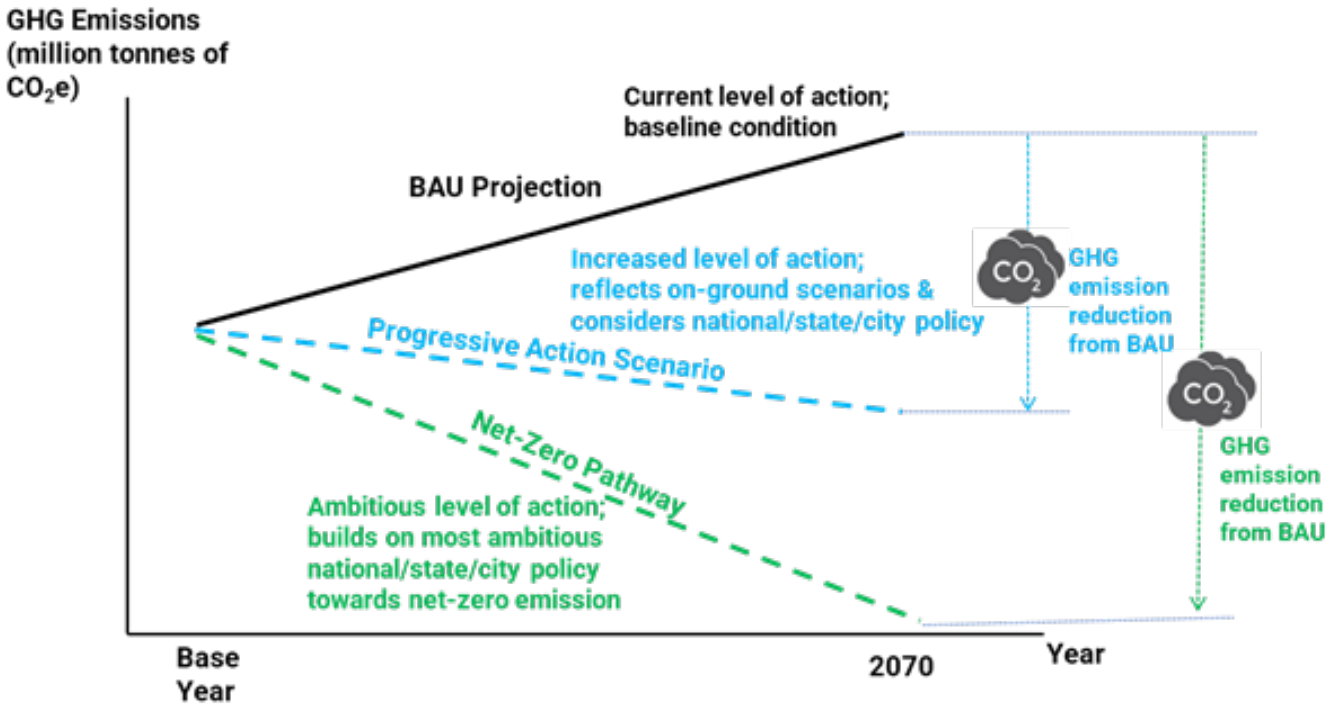


Figure 7.2: Illustration of Progressive Action and Net-zero PathwayScenarios compared to BAU Scenario

7.2 Methodology for GHG Emissions Modelling and Scenario Analysis

Tirunelveli's Net-zero CRCAP is developed based on the **Net-zero ClimateResilientCities (CRC) methodology** which includes baseline assessment of the city across sectors, GHG emissions accounting, climate risk and vulnerability assessment and identification, and prioritisation of climate resilient strategies and targets. For the two scenarios explored, the GHG emissions from baseline year 2021-22 have been projected and estimated using ICLEI South Asia's specialised Net-zero GHG Emissions Tool which aids the cities in GHG emissions mitigation planning.

The GHG emissions projection by the tool is dependent on the baseline GHG accounting undertaken for the city, socio-economic development and assumptions for sector-specific factors depending on local context. The factors that influence the GHG emissions projects are explained briefly below:

- GHG inventory and baseline: The tool integrates data from local sources, allowing for adjustments across various time periods. For Tirunelveli, emissions trajectory is estimated for 2030, 2050, and the target year of 2070.
- Population growth: Utilising the UN's World Urbanisation Prospects methodology, the tool incorporates population data, considering urbanisation rates, demographic trends, and regional variations to understand how population dynamics impact emissions.
- Economic growth: Historical economic growth patterns and relevant indicators were examined by the tool to forecast future economic development, and the results are integrated into the GHG emissions modelling and projection process.
- Sector-specific assumptions: The tool considers the anticipated evolution of sectors like energy, transportation, industry, and agriculture based on population and economic growth trends, assuming no alterations or interventions during the period of emissions trajectory.

By integrating these inputs and methodologies, the Net-zero GHG Emissions Tool establishes a technical framework for developing BAU trajectories which facilitates the exploration of various scenarios based on enhanced understanding of potential emissions trajectories if current market trends persist. Cities can utilise this tool to pinpoint opportunities and specific emissions reduction targets and undertake strategic analyses at the city level. The evidence-base of the tool empowers cities to identify and prioritise GHG emissions reduction actions and low-carbon infrastructure strategies.

The GHG Emissions Forecast Modelling involved the following assumptions:

- There is a direct correlation between emissions levels and urbanisation rate.
- Urbanisation is influenced by factors like population growth, economic development, education, birth and death rates, life expectancy, and migration.
- Urbanisation involves the expansion of urban areas due to shifts in the economy towards secondary, tertiary, or quaternary activities.
- There are three different pathways for urbanisation following rapid, moderate, and slow urbanisation rates, based on methodologies from the UN's World Urbanization Prospects, IPCC-endorsed Shared Socio-economic Pathways, and the Global Cities Institute.
- Each pathway represents varying rates of population and economic growth, with rapid urbanisation assuming the highest rates and slow urbanisation the lowest.
- Government policies play a crucial role in shaping urbanisation patterns, influencing whether urbanisation accelerates or decelerates.
- The choice of urbanisation rate and population growth rates for emissions modelling rests with city and state governments. In the case of Tirunelveli, the CRCAP adopts the slow urbanisation scenario which also aligns with Tamil Nadu State Government's population estimate for 2021 in the absence of decadal census data.

7.3 Business-as-Usual Projection of GHG Emissions in Tirunelveli

The BAU projection outlines the anticipated emissions of the city under existing conditions, without the implementation of additional climate change mitigation

measures beyond those that are already in place. The BAU projection is significant as it sheds light on the potential outcomes or consequences of maintaining status quo with respect to climate actions. It also serves as a baseline benchmark to comprehend the scale of future energy consumption and GHG emissions, emphasising the urgency for proactive measures to reduce GHG emissions. By comprehending these projections, policymakers and other stakeholders understand that adopting sustainable development practices and policies to address climate challenges are imperative to the existential threat faced by the humans.

To estimate future BAU emissions, the methodology comprises the GHG inventory baseline, population and economic growth data, and sector-specific drivers. The approach can be summarised as follows:

- Growth rates for residential, commercial, and transport sectors are determined by combining population and economic forecasts, utilising a weighted average composite methodology.
-
- The industrial sector's growth rate is derived from the baseline trend of energy consumption between 2017-18 and 2021-22. This reflects current patterns and aligns with city's priorities.
-
- Urban services and utilities such as water supply, solid waste, and domestic wastewater employ a service demand approach. This approach assumes that anticipated changes in population will be the primary driver of demand for municipal services.

Table 1 reflects the base growth rates used for population and GDP for Tirunelveli city.

Table 7.1: Population and economic growth rates used in BAU projection for Tirunelveli

Parameter	Annual Average Growth Rates (%)				
	2022-2030	2031-2040	2041-2050	2051-2060	2061-2070
Population Growth Rate	2.16	1.10	1.10	0.68	0.64
Economic Growth Rate	8.38	4.43	2.60	2.38	2.38

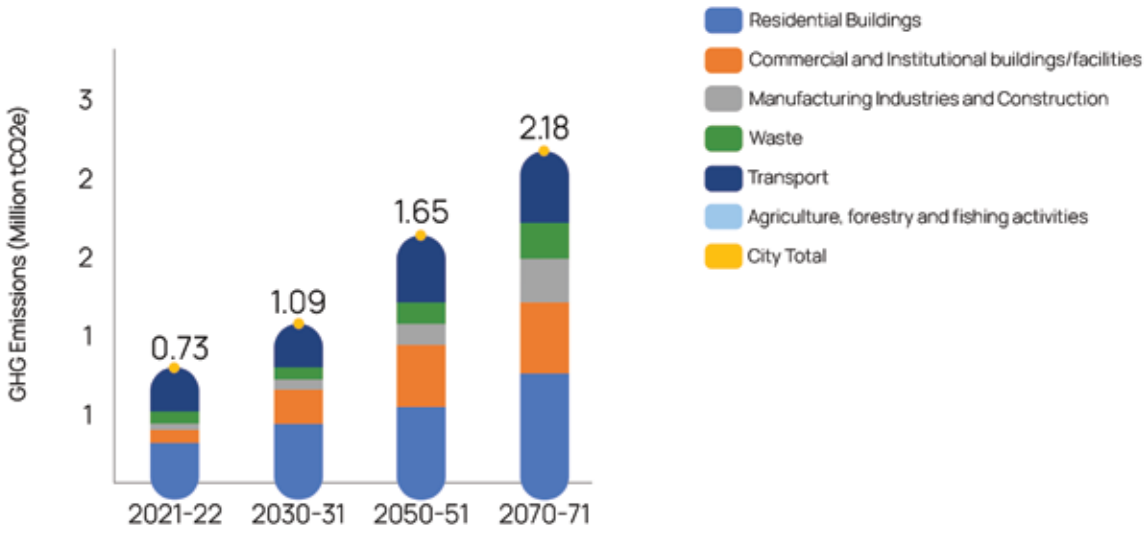


Figure 7.3: GHG emissions estimate in BAU projection for Tirunelveli by 2070

From Figure 7.3, it is evident that if the BAU scenario where no additional measures or climate actions are implemented continues, Tirunelveli would contribute 2.18 million tCO2e by 2070 which is three times the current quantity of GHG emissions from the city (0.73 million tCO2e in 2021-22).

In the BAU projection, the anticipated rise in GHG emissions until 2070 is primarily driven by the stationary energy sector, which includes energy consumption by buildings and AFOLU activities in Tirunelveli. It is estimated that GHG emissions from stationary energy use will account for 69.3% of Tirunelveli's total emissions by 2070.

The increasing trend in emission levels within the stationary energy sector is largely influenced by residential and commercial buildings. Historically, Tirunelveli has been the epicentre of development in the southern districts of Tamil Nadu, known for its renowned institutions and educational services which drive significant energy demand. In the BAU scenario, this demand is expected to be met primarily through grid-based electricity and fossil fuels, contributing to the city's GHG emissions.

The transport sector is the next major contributor to GHG emissions in Tirunelveli. This is due to high reliance on private vehicles, inadequate public transport services to remote locations, and the absence of a mass rapid transit system such as Bus Rapid Transit System (BRTS). Two-wheelers, being the most convenient mode of transportation, dominate the roads and significantly contribute to emissions.

While GHG emissions from industrial buildings and the waste sector are projected to increase, they remain comparatively lower than those from residential and commercial buildings and the transportation sector.

Although Tirunelveli is not an industrial city, the planned development of industrial corridors and SEZs in the vicinity indicates potential future industrial growth. Additionally, the ISRO satellite launch pad at Kulasekarapattinam, about 50 km from the city, is expected to spur urbanisation and industrial activity in and around the city.

Tirunelveli is developing infrastructure to manage solid waste and enhance wastewater management, including the implementation of Phase II and Phase III of the UGSS. However, the increasing population and expansion of services will increase GHG emissions from the waste sector, underscoring the need for sustainable waste management infrastructure and systems.

7.4 Progressive Action Scenario

The Progressive Action Scenario aligns with the goals and targets set by national and state governments across various sectors through policies, programs, and missions. It also includes all ongoing projects and city-level policies, including climate initiatives with administrative approvals. This scenario advocates for more ambitious actions and targets compared to the current state, while considering on-ground realities, local conditions, available resources, and constraints.

The key existing policies and commitments considered to build this scenario include:

- Nationally Determined Contributions (NDC), 2015; updated NDC submitted in 2021
- National Action Plan for Climate Change (NAPCC), 2008 (including National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, Green India Mission, National Mission for Sustainable Agriculture)
- Mission LiFE, India Cooling Action Plan, National Clean Air Program
- Energy Conservation Building Code, 2017 and Eco-Niwas Samhita, 2018
- Swachh Bharat Mission (Clean India Campaign)
- Tamil Nadu Action Plan for Climate Change, 2021
- State policies on RE: Tamil Nadu Solar Policy, 2019; Tamil Nadu Wind Power Policy, 2016; Tamil Nadu Electric Vehicle Policy, 2020
- Renewable Purchase Obligation (RPO) targets for TANGEDCO
- Tamil Nadu Climate Change Mission
- Green Tamil Nadu Mission
- Tamil Nadu Wetland Mission
- Tirunelveli Comprehensive Mobility Plan
- Tirunelveli Master Plan 2021 for Horizon Year 2041

While setting targets for EE measures in this scenario, the goals and initiatives of national policies and

Table 7.2: Sector-wise projected GHG emissions in BAU projection for Tirunelveli

Parameter	GHG Emissions in Million tCO2e				
	Baseline 2021-22	Projected	2041-2050	2051-2060	2061-2070
Stationary Energy	0.47	0.72	1.12	1.51	69.3%
Residential Buildings	0.30	0.42	0.59	0.73	33.6%
Commercial and Institutional Buildings	0.11	0.20	0.36	0.53	24.3%
Manufacturing Industry and Construction	0.05	0.09	0.17	0.25	11.4%
Agriculture, Forestry, and Fishing Activities	0.0001	0.0002	0.0002	0.0003	0.01%
Transport	0.19	0.27	0.38	0.47	21.6%
Waste	0.07	0.10	0.15	0.20	9.1%
City Total	0.73	1.09	1.65	2.18	100%

missions, such as the National Mission for Enhanced Energy Efficiency and the Energy Efficiency Financing Platform (EEFP), are considered, along with the market maturity of certain measures or interventions. Increased integration of RE is crucial for achieving net-zero goals for Tirunelveli. The progression of solar PV deployment aligns with the Tamil Nadu Solar Energy Policy 2019 and is adjusted to reflect the current state of solar PV implementation in the city.

For transport sector strategies, the goals and targets for EV deployment are aligned with the National EV Policy of the GoI, while the shift in mode-share and the development of NMT are aligned to be within the scope of Tirunelveli's Comprehensive Mobility Plan.

The actions proposed for SWM and wastewater management are based on the existing scenarios in these sectors, the Solid Waste Management Strategies and Action Plan prepared by the city, and the least emitting treatment pathways for solid and liquid waste as outlined in the Central Public Health and Environmental Engineering Organisation (CPEEHO) manual of India.

Results and Highlights

Based on the analysis of all actions and targets set under the Progressive Action Scenario, **the GHG emissions for Tirunelveli are estimated to reduce by 55.5% (1.21 million tCO2e) in 2070 compared to the BAU scenario.**

The Progressive Action Scenario results in the following levels of emissions reduction compared to BAU:

- GHG emissions in 2030: 26.8% lower than BAU
- GHG emissions in 2050: 42.4% lower than BAU
- GHG emissions in 2070: 55.5% lower than BAU

Table 7.3: GHG emissions reduction by sector compared to BAU projection for Progressive Action Scenario

Land Use Classification	2019		2021		2023	
	Emissions Reduction (Million tCO2e)	Emissions Reduction from Sectoral BAU Emissions (%)	Emissions Reduction (Million tCO2e) Area (sq km)	Emissions Reduction from Sectoral BAU Emissions (%)	Emissions Reduction (Million tCO2e) Area (sq km)	Emissions Reduction from Sectoral BAU Emissions (%)
Residential Buildings	0.16	39%	0.36	62%	0.69	94%
Commercial and Institutional Buildings and Facilities	0.12	58%	0.26	73%	0.50	95%
Manufacturing Industries and Construction	0.01	15%	0.03	21%	0.07	27%
Transport	0.13	49%	0.22	57%	0.43	91%
Waste	0.05	44%	0.09	62%	0.14	71%
Total	0.47	43.2%	0.97	58.9%	1.83	83.9%

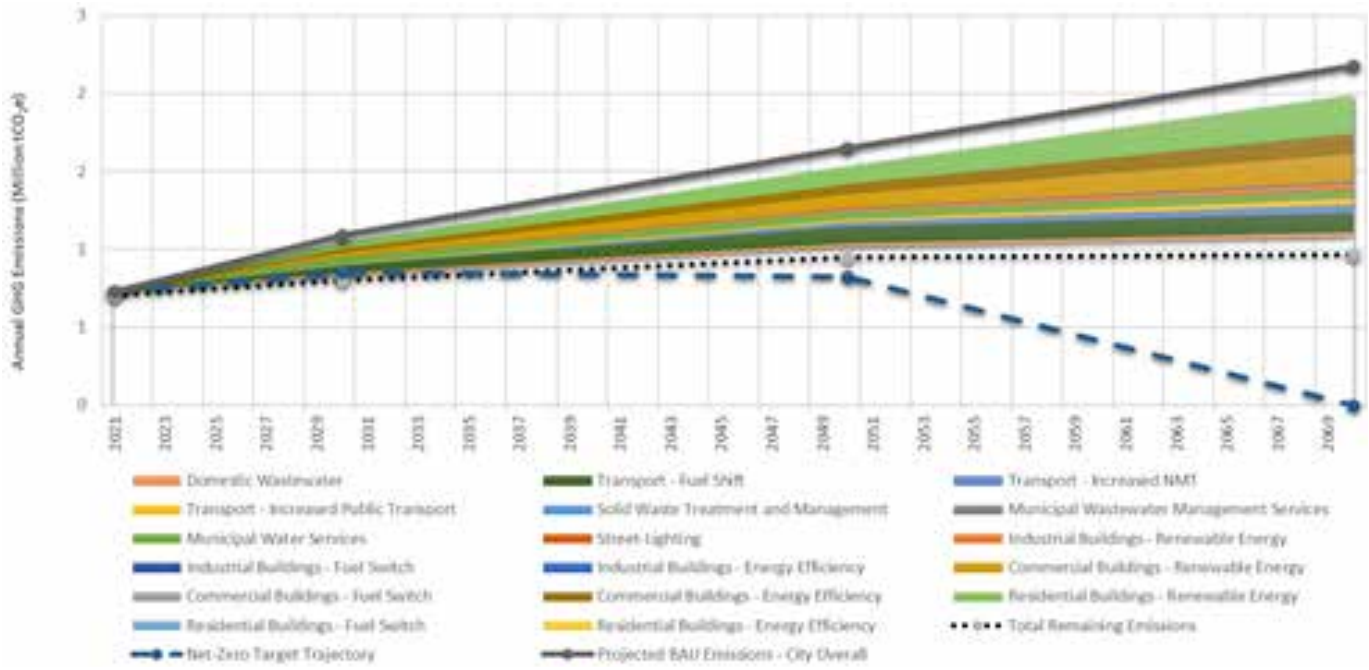


Figure 7.4: GHG emissions mitigation trend for Progressive Action Scenario, 2021 to 2070

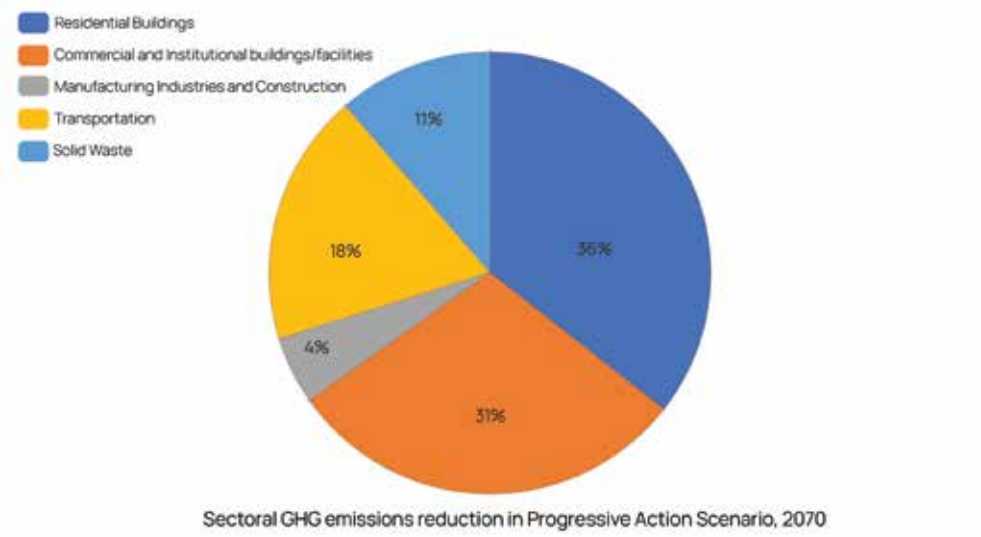


Figure 7.5: Sectoral GHG emissions reduction in Progressive Action Scenario, 2070

In the Progressive Action Scenario, climate change mitigation actions and targets across sectors result in a total emissions reduction of about 55.5% compared to projected BAU emissions. Stationary energy use in buildings, the main contributor to GHG emissions in the BAU scenario, accounts for 69.2% of projected BAU emissions by 2070. Consequently, EE and RE strategies targeting building energy consumption alone contribute approximately 69% of the GHG emissions reduction in the Progressive Action Scenario (Figure 7.5).

The Progressive Action Scenario recommends that more than 75% lighting and fans in all building types should be energy efficient by 2070. Additionally, at least 50% new buildings should be constructed as green buildings, and RE should contribute 35% to 70% of electricity consumption across different building typologies in the city.

Following stationary energy use in buildings, the transportation sector is the second largest contributor to GHG emissions in the city, accounting for 21.6% of BAU emissions. To mitigate this, it is recommended that at least 35% of all vehicles should be electric, with 60% of these fully powered by renewable-generated electricity, to meet the Progressive Action Scenario targets.

Considering Tirunelveli city's goal of achieving source segregation and its plan to deploy 50 TPD capacity MRF and windrow composting plants for bio-degradable waste treatment and dry waste recycling, along with the ongoing RE initiatives by TCMC, significant emissions reductions can be achieved in the waste and municipal services sector.

The Progressive Action Scenario aligns with existing and proposed regional and national government policies, leading to substantial GHG emissions reductions compared to the BAU scenario. Under this scenario, GHG emissions are projected to be reduced by about 55.5% by 2070, compared to the BAU scenario where emissions are expected to triple from the baseline year. To further reduce the remaining 44.5% of GHG emissions and progress towards a net-zero emissions trajectory, Tirunelveli city must identify strategic actions and set ambitious targets for 2070. The Net-zero Pathway Scenario has been developed to outline the ambitious actions required to achieve this goal.

7.5 Net-zero Pathway

The Net-zero Pathway Scenario outlines the necessary climate actions for Tirunelveli to achieve net-zero GHG emissions by 2070. This scenario aligns with the GoI's commitment at COP 26 in Glasgow to reach net-zero emissions by 2070. The proposed actions in this scenario may exceed the ambitious goals and targets set in various policies, missions, and programs of the GoI, GoTN, and TCMC.

While setting targets for the Net-zero Pathway Scenario, the goals and targets from the schemes and programs considered in the Progressive Action Scenario serve as the foundation. These targets are then expanded to achieve higher GHG emissions reductions. The implementation of these actions may require relevant framework, regulations, or policies, making them dependent on national, sub-national, and local

interventions in line with future developments such as technological advancements, demographic changes, and economic growth. Additionally, implementing these ambitious actions will necessitate a significant increase in financial support from state and national governments, supplemented by international climate financing initiatives.

Results and Highlights

Analysing the actions and targets of Net-zero Pathway Scenario shows that Tirunelveli's GHG emissions reduce by 83.9% (1.83 million tCO2e) in 2070 compared to BAU.

The Net-zero Pathway Scenario results in the following levels of emissions reduction compared to BAU:

- GHG emissions in 2030: 43.2% lower than BAU
- GHG emissions in 2050: 58.9% lower than BAU
- GHG emissions in 2070: 83.9% lower than BAU

Table 7.4: GHG emissions reduction by sector compared to BAU for Net-zero Pathway Scenario

Land Use Classification	2019		2021		2023	
	Emissions Reduction (Million tCO2e)	Emissions Reduction from Sectoral BAU Emissions (%)	Emissions Reduction (Million tCO2e) Area (sq km)	Emissions Reduction from Sectoral BAU Emissions (%)	Emissions Reduction (Million tCO2e) Area (sq km)	Emissions Reduction from Sectoral BAU Emissions (%)
Residential Buildings	0.16	39%	0.36	62%	0.69	94%
Commercial and Institutional Buildings and Facilities	0.12	58%	0.26	73%	0.50	95%
Manufacturing Industries and Construction	0.01	15%	0.03	21%	0.07	27%
Transport	0.13	49%	0.22	57%	0.43	91%
Waste	0.05	44%	0.09	62%	0.14	71%
Total	0.47	43.2%	0.97	58.9%	1.83	83.9%

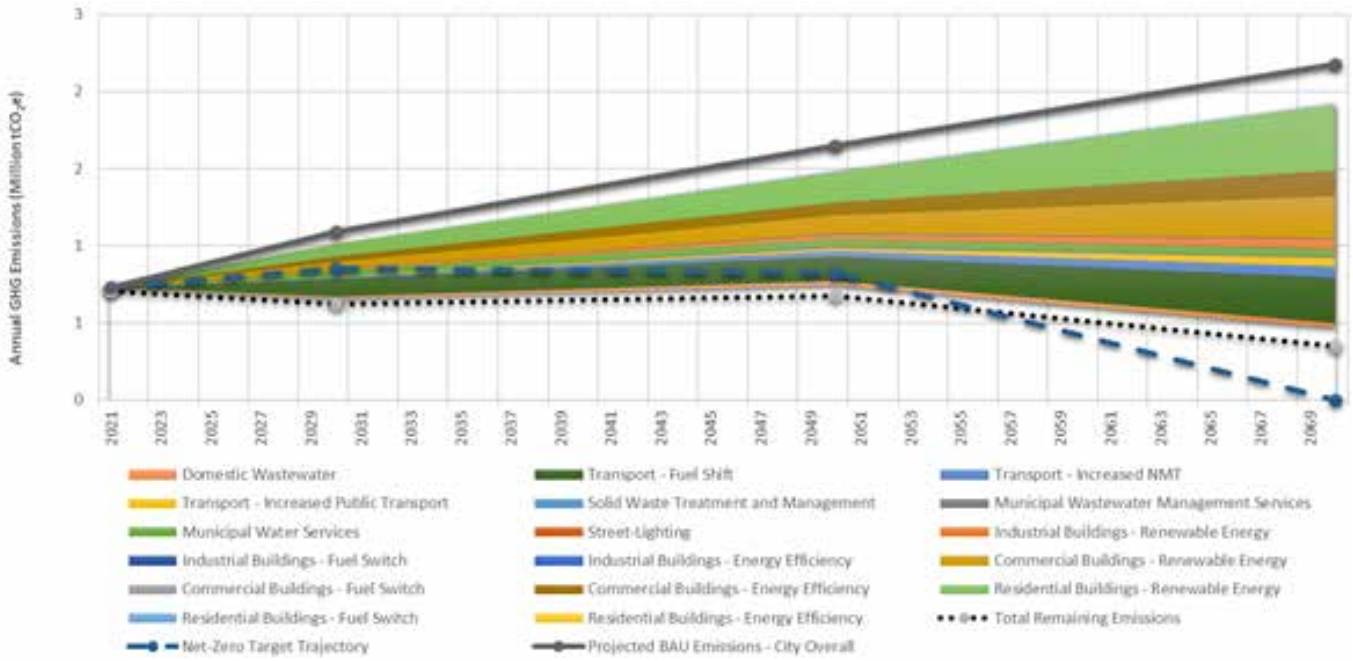


Figure 7.6: GHG emissions mitigation trend for Net-zero Pathway Scenario, 2021 to 2070

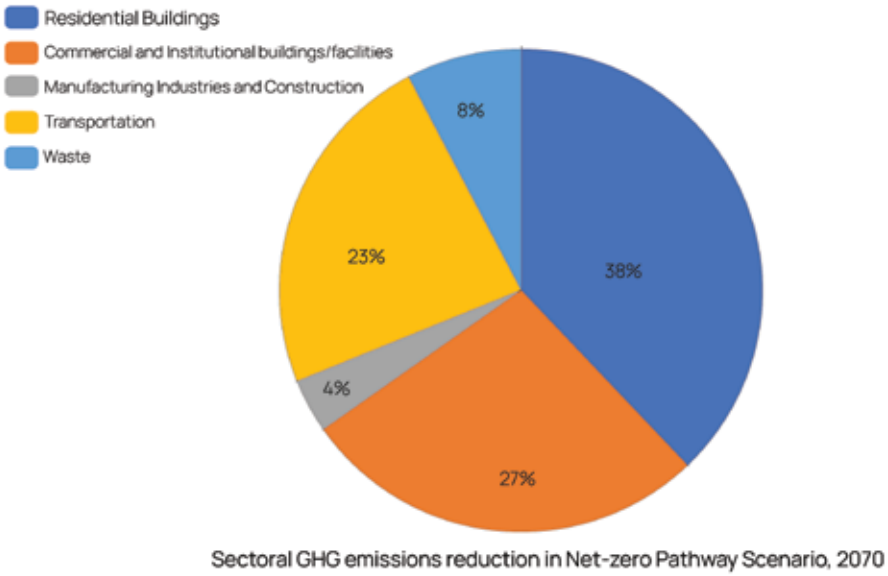


Figure 7.7: Sectoral GHG emissions reduction in Net-zero Pathway Scenario, 2070

In the Net-zero Pathway Scenario, ambitious sectoral actions and targets enable Tirunelveli to reduce GHG emissions by 83.9% from its projected BAU emissions. Given the major contributions of residential and commercial buildings and the transportation sector to the city's GHG emissions, integrating EE measures and RE into building energy consumption, as well as shifting to cleaner fuels for transportation, are key actions required to achieve net-zero emissions by 2070.

The Net-zero Pathway Scenario recommends that by 2070, 100% of lighting and fans in buildings should be energy efficient, at least 50% of new buildings should be constructed as green buildings, and RE should account for at least 50% of electricity consumption in buildings. In the transportation sector, 90% of all vehicles must be electric and powered almost entirely by renewable-generated electricity to meet net-zero targets. Ambitious goals for the deployment of MRFs for recovery and recycling of waste, and production of bio-CNG from waste are also considered.

Given the city's implementation of a megawatt-scale solar PV plant for captive consumption and rooftop solar PV plants over 36 of its buildings, and its goal for high RE integration into municipal energy consumption, large-scale integration of renewable solar and wind power into municipal utilities, such as water supply and wastewater treatment, is proposed.

If successfully achieved, these ambitious goals will steer Tirunelveli towards a sustainable future with net-zero emissions.

7.5.1 Residual Emissions in Net-zero Pathway Scenario

Despite the ambitious targets set in Tirunelveli's Net-zero Pathway Scenario, achieving an 83.9% reduction in GHG emissions from BAU levels by 2070, residual emissions of 16.1% (0.35 million tCO2e) still need to be addressed. Reducing these residual emissions is crucial for Tirunelveli to achieve net-zero status by 2070. Further reductions can be achieved through interventions such as full grid decarbonisation, nature-based climate solutions, resource circularity, and utilisation of local carbon sinks.

For instance, the city's green cover offers significant potential for carbon sequestration. Currently, the city's urban green cover constitutes 25.32% of Tirunelveli's land use (27.5 sq km), translating to a per capita green cover of 49.62 sq m, well above the WHO-recommended 9 sq m per person.

While Tirunelveli has adequate green spaces now, future urban development may alter this balance. According to the Tirunelveli Master Plan 2021, dry agricultural lands, currently accounting for 20.24% of the city's area, are designated for institutional and mixed residential purposes by 2041, indicating a significant reduction in open and green spaces. However, maintaining the current tree cover of 25.32% could sequester up to 0.88 million tCO2e. Thus, preserving and expanding tree cover with native species can significantly enhance the city's carbon sequestration potential and support in achieving its net-zero targets.

Implementing the strategies outlined in this Net-zero CRCAP and achieving net-zero targets will require substantial policy support, enabling regulatory and institutional frameworks, capacity building, and financial support from state, national, and international sources. Periodic reviews of the Net-zero CRCAP are necessary to ensure sustained support and updates to policy, capacity building, climate finance, and other aspects until 100% reduction of BAU GHG emissions is achieved. TCMC commits to collaborating with key departments and stakeholders to realise their net-zero vision ahead of schedule.

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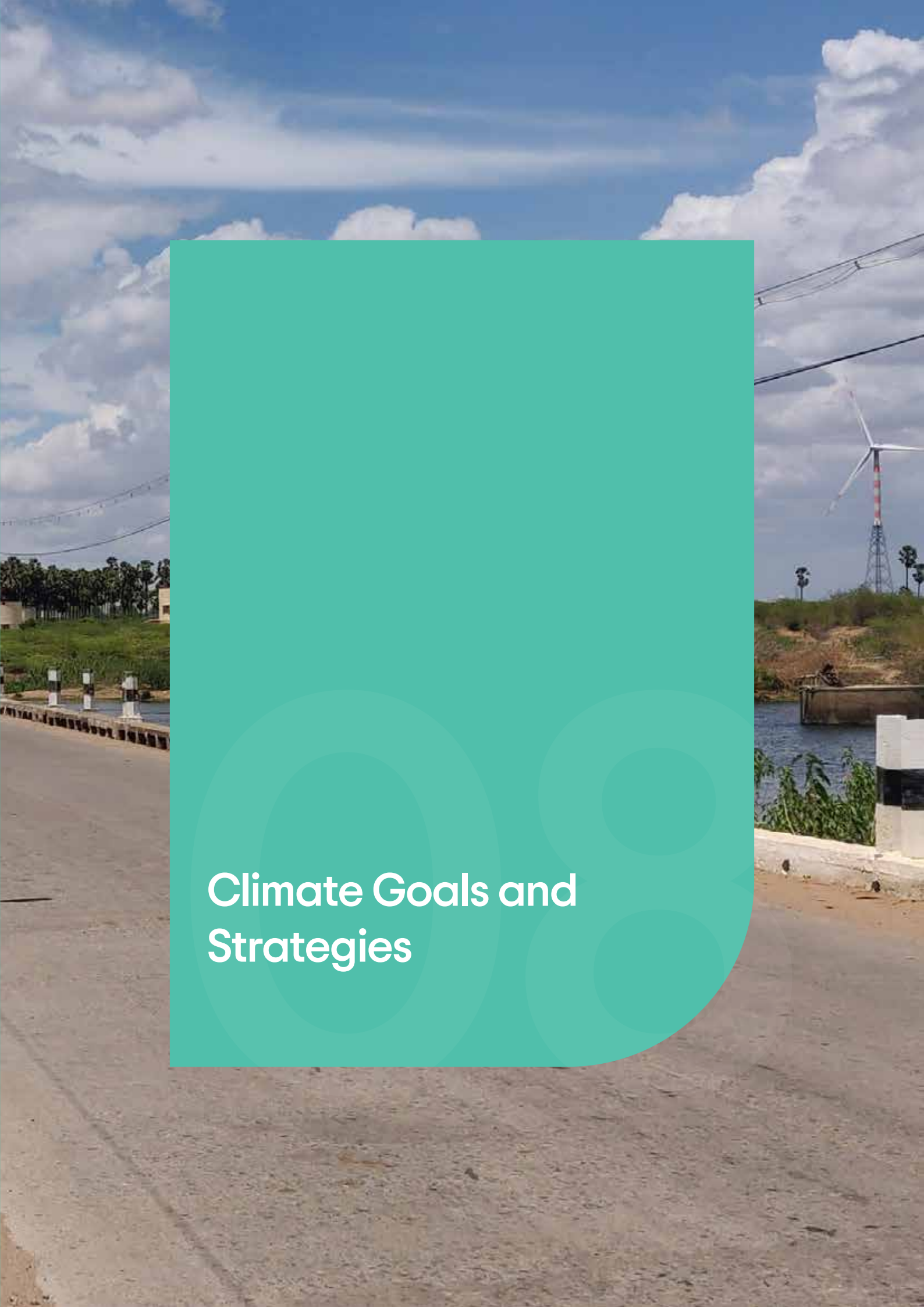


Climate Goals and Strategies

Tirunelveli's CRCAP is a collaborative effort, driven by a Climate Core Team at TCMC and involving diverse stakeholders, including government departments, NGOs, and community representatives. The plan is informed by extensive data analysis and experience, ensuring a comprehensive approach to address the city's priorities.

With a focus on data-driven decision-making, Tirunelveli's climate action planning process conducts thorough vulnerability assessments across key sectors. By analysing vulnerabilities in water resources, waste management, and urban greening, among others, policymakers gain valuable insights for prioritising actions and resource allocation.

By integrating vulnerability assessments with GHG emissions modelling, Tirunelveli establishes ambitious goals and targets for mitigation and adaptation strategies. This evidence-based approach guides the city's climate action planning to effectively address diverse challenges and ensure resilience.

8.1 Tirunelveli's Vision, Sectoral Goals and Targets

By developing this Net-zero CRCAP and setting ambitious climate goals and targets, TCMC aims to guide Tirunelveli city towards a net-zero emissions future, prioritising resilience against urban heat, flooding, and resource challenges while emphasising equity and gender considerations. By integrating blue-green spaces and climate resilient infrastructure, we're shaping a sustainable city that prioritises residents' well-being and preserves natural ecosystems to enhance the city's liveability.

Tirunelveli city, with an economy leaning towards commercial and institutional services, will aim to build and operate greener and energy-efficient buildings that prioritise thermal comfort and are powered by RE

Sector	Built Environment and energy	Transport	Water Supply
Goals	Transition to an energy efficient and heat resilient city by adopting low-emission strategies for the built environment.	Encourage development of zero-emission transport infrastructure and adoption of clean mobility options.	Augment water resilience of the city and reuse 100% of treated wastewater to meet commercial and industrial water demand.
Target	Up to 80% of new buildings adopt green building principles by 2070. 100% energy efficient lighting and fans in new and existing buildings Up to 65% of energy demand met by RE	Shift 8% of motorised trips to public transport and 10% to NMT by 2070. Shift 90% of all vehicles to low-emission vehicles by 2070.	90% adoption of energy-efficient equipment for water supply and 40% of energy demand to be met by RE sources Reduce NRW to 15% by 2050 and 10% by 2070.

to achieve its ambitious net-zero emissions status. It also aims to transition to cleaner mobility options by adopting hybrid and electric vehicles powered by renewable resources. Tirunelveli will also strive to be a circular economy by embracing a zero-waste approach that will minimise environmental impact of solid waste and maximise resource efficiency.

Tirunelveli's Vision for a Net-zero Climate Resilient Future: To contribute to India's fight against climate change, and to lead as example for all tier-3 cities in India by transitioning towards a net-zero emissions future and building climate resilience of the city in the face of increasing climate risks from flooding and heat waves.

Climate Change Adaptation Goal: Tirunelveli city aims to enhance its resilience to extreme rainfall and heat events through improved planning and management, infrastructure development and by adopting climate sensitive and nature-based solutions.

GHG Emissions Mitigation Target:

GHG Emissions in 2030: 43.2%
GHG Emissions in 2050: 58.9%
GHG Emissions in 2070: 83.9%

Tirunelveli will update its net-zero targets during future revisions of this CRCAP and consider adoption of emerging technologies and strategies to achieve 100% GHG emissions reduction from BAU scenario by 2070 and to ensure the city's resilience to future impacts of climate change.

Waste Water	Storm Water	Solid Waste	Urban Green Cover & Biodiversity
100% treatment and reuse of wastewater generated in the city	Increase resilience to urban flooding and riverine flooding during extreme rainfall events.	Transition towards circular economy by adopting measures to develop a zero-waste city.	Rejuvenate urban natural ecosystems and increase green cover to enhance climate resilience of the city.
90% adoption of energy-efficient equipment for wastewater infrastructure and 60% of energy demand to be met by RE sources 100% new plants use anaerobic treatment with methane gas capture and reuse.	Increase coverage of stormwater drain network as per CPHEEO guidelines by 2050.	Low-emission waste collection systems for 100% waste collection 100% scientific waste processing, treatment, and disposal by 2030.	Maintain green cover in the city at existing levels by 2070 and increase dense tree canopy.

Sector	Built Environment and energy	Transport	Water Supply
Strategies	Encourage use of green building principles to design thermally comfortable and high-performance buildings. Mandate targeted energy performance measures and green building standards for buildings. Transition to a clean powered local grid to meet the city's energy demand.	Develop NMT (biking and walking), infrastructure and improve efficiency of public transit. Encourage adoption of low-emission mobility options and development of RE powered transport infrastructure. Integrated planning and development of transport infrastructure and adoption of smart traffic management systems.	Frame local policies and rules for water conservation. City-wide coverage and 24X7 water supply through an efficient water distribution network with reduced NRW. Undertake ecological restoration of lakes and Thamirabarani riverfront to enhance water resilience of city. Equip water supply network with energy efficient systems powered by RE.

8.1.1 Built Environment & Energy

Goal: Transition to an energy efficient and heat resilient city by adopting low-emission strategies for the built environment.

Mitigation Targets:

- Up to 60% of new buildings adopt green building principles by 2070.
- 100% energy efficient lighting and fans in new and existing buildings
- Up to 65% of energy demand met by renewable energy

Tirunelveli has realised the potential of reducing energy consumption and associated bills by early adoption of LED streetlighting, and implementation of rooftop solar PV plants on municipal buildings. The city also implemented a 5 MW solar PV plant for municipal consumption. Energy demand will have to be reduced further to reap the benefits of energy transition. The city's intent is to further integrate RE and implement energy efficient and thermally comfortable design and green building practices in municipal buildings and encourage similar efforts across the city. This approach has helped optimise the scale of deployment and investment in RE to meet the remaining energy requirements. The following strategies will help achieve goals and targets related to built environment and energy:

Strategy 1: Encourage use of green building principles to design thermally comfortable and high-performance buildings.

Strategy 2: Mandate targeted energy performance measures and green building standards for buildings.

Strategy 3: Transition to a clean powered local grid to meet the city's energy demand.

8.1.2 Transport

Goal: Encourage development of zero-emission transport infrastructure and adoption of clean mobility options.

Waste Water	Storm Water	Solid Waste	Urban Green Cover & Biodiversity
City-wide coverage of sewerage network; Equip wastewater collection network and treatment facilities with energy efficient equipment powered by RE. Implement septage management measures to treat and recycle sludge to minimise environmental hazards. Enhance operational and energy performance of wastewater infrastructure using energy efficient equipment and low-emission processes.	Watershed management of natural drains in the city through sustainable urban planning practices to prevent urban flooding Rejuvenation of lakes to enable them to act as flood buffers and natural groundwater recharge areas. City-wide coverage of stormwater drainage network and implementation of nature-based solutions for stormwater management	Promote circular economy practices to transition to zero-waste city by minimising solid waste generation and maximising reuse and recycling of waste. Achieve 100% source segregation and develop decentralised waste recovery facilities. Develop scientific waste processing and treatment facilities to minimise environmental hazards of waste management and disposal.	Rejuvenate existing natural ecosystems in the city and promote native species for urban green and biodiversity measures. Develop blue-green infrastructure in the city and microhabitats to enrich local biodiversity. Enhance carbon sequestration through urban greening measures.

Mitigation Targets:

- Shift 8% of motorised trips to public transport and 10% to NMT by 2070.
- Shift 90% of all vehicles to low-emission vehicles by 2070.

The transport sector is not directly under the ambit of city administration. However, given that it is a major GHG emissions contributor, it is imperative that the city administration collaborate with the state transport authority to enable EV adoption in the public transport fleet to meet the targets of National EV Policy. Tirunelveli will prioritise the development of dedicated infrastructure such as pedestrian footpaths and cycle tracks to encourage NMT in the city and develop road networks to better connect the city through public transport. Ensuring that more people opt for public transport will help reduce private vehicles on the roads, resulting in lower emissions and improved air quality. Building on the efforts of GoTN, Tirunelveli will enhance the EV public charging infrastructure powered by RE to support EV adoption in the city. Goals and targets related to reducing carbon footprint of the transport sector will be achieved through the following

key strategies:

Strategy 1: Develop NMT infrastructure and enhance capacity and efficiency of public transit.

Strategy 2: Encourage adoption of low-emission mobility options and development of RE powered transport infrastructure.

Strategy 3: Integrated planning and development of transport infrastructure and adoption of smart traffic management systems

8.1.3 Water

Goal: Augment water resilience of the city and reuse 100% of treated wastewater to meet commercial and industrial water demand.

Mitigation Target: Water

- 90% adoption of energy-efficient equipment for water supply and 40% of energy demand to be met by RE sources

- Reduce NRW to 15% by 2050 and 10% by 2070.

Tirunelveli has made sustainable and integrated urban water management a top priority amid growing water scarcity and shifting precipitation patterns. Additionally, there's a strong focus on incorporating RE and energy efficient equipment into municipal infrastructure for water supply and wastewater management. The objective within the water sector is to diversify water supply resources and bolster water resilience by moving towards reuse of 100% of the treated wastewater. This will be accomplished through the implementation of the following strategies:

Water

Strategy 1: Frame local policies and rules for water conservation.

Strategy 2: City-wide coverage and 24X7 water supply through an eicient water distribution network with reduced NRW

Strategy 3: Undertake ecological restoration of lakes and Thamirabarani riverfront to enhance water resilience of the city.

Strategy 4: Equip water supply network with energy efficient systems powered by RE.

8.1.4 Wastewater

Goal: 100% treatment and reuse of wastewater generated in the city

Mitigation Target:

Wastewater

- 90% adoption of energy-efficient equipment for wastewater infrastructure and 45% of energy demand to be met by RE sources
- 100% new plants use anaerobic treatment with methane gas capture and reuse.

Tirunelveli is expanding the coverage of UGSS network to improve wastewater collection and prevent wastewater from reaching its water bodies, especially Thamirabarani River, and from mixing with stormwater during rainfall events which often leads to public health challenges. Tirunelveli also aims to augment its wastewater treatment capacity using advanced technologies such as Sequential Batch Reactor (SBR), methane recovery systems and tertiary treatment systems to treat 100% wastewater. This will be accomplished through the implementation of the following strategies:

Wastewater

Strategy 1: City-wide coverage of sewerage network; Equip wastewater collection network and treatment facilities with energy efficient equipment powered by RE.

Strategy 2: Implement septage management measures to treat and recycle sludge to minimise environmental hazards.

Strategy 3: Enhance operational and energy performance of wastewater infrastructure using energy efficient equipment and low-emission processes.

8.1.5 Stormwater

Goal: Increase resilience to urban flooding and riverine flooding during extreme rainfall events.

Tirunelveli has embraced a comprehensive approach that places emphasis on implementing robust stormwater management initiatives at the watershed scale. This strategy aims to not only mitigate flood risk but also foster sustainable water resource management. By enhancing the stormwater drainage network and integrating nature-based solutions such as bio-retention, green spaces and corridors, groundwater recharge structures and increasing permeable surfaces, the city aims to effectively capture excess rainwater, safeguard flood-prone areas, and facilitate groundwater recharge. By implementing the following strategies, Tirunelveli aims to build a more resilient urban environment capable of effectively managing flood events while promoting sustainable water management practices:

Strategy 1: Watershed management of natural drains in the city through sustainable urban planning practices to prevent urban flooding

Strategy 2: Rejuvenation of lakes to enable them to act as flood buffers and natural groundwater recharge areas

Strategy 3: City-wide coverage of stormwater drainage network and implementation of nature-based solutions for stormwater management

8.1.6 Solid Waste

Goal: Implement circular economy approaches to transition into a zero-waste city.

Mitigation Target:

- Low-emission waste collection systems for 100% waste collection
- 100% scientific waste processing, treatment, and disposal by 2070

Tirunelveli is committed to a comprehensive approach to waste management, guided by the principles of the circular economy. The city's goal is to minimise waste generation, maximise resource recovery, and mitigate the environmental impact of waste disposal by adopting scientific approaches. This entails achieving source segregation through community engagements; enhancing efficient primary and secondary waste collection; expanding and improving the efficiency of existing processing infrastructure with composting facilities; and establishing centralised and decentralised MRFs, transfer stations, waste-to-energy and bio-CNG plants. Maximising plastic and recyclable waste recovery through effective management and establishing connections between MRFs, manufacturers, recyclers, and eco-parks will be prioritised. Educational outreach programs will further support these waste management strategies. The goal in waste management is to achieve 100% source segregation by 2030 and become a zero-waste city by 2070 by adopting the following strategies:

Strategy 1: Promote circular economy practices to transition to zero-waste city by minimising solid waste generation and maximising reuse and recycling of waste.

Strategy 2: Achieve 100% source segregation and develop decentralised waste recovery facilities.

Strategy 3: Develop scientific waste processing and treatment facilities to minimise environmental hazards of waste management and disposal.

8.1.7 Urban Greening and Biodiversity

Goal: Rejuvenate urban natural ecosystems and improve the health of existing green cover in the city.
Mitigation Target: Improve the health of existing green cover in the city at existing levels by 2070 and increase tree canopy density.

Tirunelveli has many water bodies including canals, lakes, and Thamirabarani river while a significant area of the city is under green cover. Tirunelveli's goals for climate resilience through urban greening and biodiversity sector include rejuvenation of its natural eco-systems, development of blue-green infrastructure, and improvement of health of existing green cover in the city. TCMC will collaborate with Tamil Nadu Forest Department through the Local Biodiversity Strategy and Action Plan (LBSAP) and establish green corridors and urban forests using native tree species. This will help improve the health of green cover, conserve local biodiversity and enhance ecosystem services. Tirunelveli will also capitalise on the carbon sequestration potential of its green cover to achieve its net-zero emission targets. Tirunelveli will pursue the following strategies to achieve these goals:

Strategy 1: Improve the health of green cover with use of native species for plantation.

Strategy 2: Develop blue-green infrastructure in the city and microhabitats to enrich local biodiversity.

Strategy 3: Enhance carbon sequestration through urban greening measures.

8.2 Net-zero Tirunelveli by 2070 through Net-zero Emissions Pathway

Tirunelveli's mitigation objective demonstrates its aim to achieve net-zero GHG emissions by 2070, aligning with India's broader net-zero goals. In the climate action planning process, two emission reduction scenarios—the Progressive Action scenario and the Net-zero Pathway—were developed to identify strategies and actions to be undertaken by Tirunelveli. These scenarios outline the scale of measures required for Tirunelveli to progress toward achieving net-zero emissions by 2070.

Implementing the strategies and actions outlined in the Net-zero Pathway will enable Tirunelveli to achieve substantial GHG emissions reductions at the city level, amounting to as much as 91% compared to business-as-usual (BAU) scenarios. This progress will significantly advance Tirunelveli towards its net-zero emissions target.

The Net-zero Pathway helps reduce Tirunelveli's GHG emissions by 83.9% in 2070 compared to the BAU scenario. This corresponds to GHG emissions reduction of 1.83 million tCO2e by 2070.

The Net-zero Pathway results in the following levels of emissions reduction compared to BAU:

GHG Emissions in 2030: 43.2% lower than BAU

GHG Emissions in 2050: 58.9% lower than BAU

GHG Emissions in 2070: 83.9% lower than BAU

In the Net-zero Pathway, the ambitious sectoral actions and targets helped Tirunelveli to reduce GHG emissions by 83.9% from its city-scale projected BAU emissions.
Given the major contribution by residential and commercial buildings and transportation sector to the GHG emissions from the city, ambitious targets to integrate EE measures and RE into building energy consumption, and fuel shift for Transportation are considered key actions required for the city to achieve net-zero emissions by 2070.

The Net-zero Pathway recommends that 100% lighting and fans in buildings should be energy efficient by 2070, at least 60% new buildings should be constructed as green buildings, and that RE should contribute to at least 60% electricity consumption by buildings in the city.

In the transportation sector, 90% of all vehicles must be electric and should be fully powered by renewable generated electricity to meet net-zero targets. Considering Tirunelveli's goal to achieve source-segregation by 2030, ambitious targets for MRF deployment, recycling of waste and production of bio-CNG from waste are considered.

Considering that the city already implemented a MW scale solar PV plant, and its goal of high RE integration for municipal consumption, ambitious actions on the large-scale integration of renewable solar and wind power into municipal utilities such as water supply and wastewater treatment are proposed.

If successfully achieved, these ambitious goals will steer Tirunelveli towards a sustainable future with net-zero emissions.

Table 8.1: GHG emissions reduction by sector for Net-zero Pathway

Land Use Classification	2019		2021		2023	
	Emissions Reduction (Million tCO2e)	Emissions Reduction from Sectoral BAU Emissions	Emissions Reduction (Million tCO2e) Area (sq km)	Emissions Reduction from Sectoral BAU Emissions (%)	Emissions Reduction (Million tCO2e) Area (sq km)	Emissions Reduction from Sectoral BAU Emissions (%)
Residential Buildings	0.16	39%	0.36	62%	0.69	94%
Commercial and Institutional Buildings and Facilities	0.12	58%	0.26	73%	0.50	95%
Manufacturing Industries and Construction	0.01	15%	0.03	21%	0.07	27%
Transport	0.13	49%	0.22	57%	0.43	91%
Waste	0.05	44%	0.09	62%	0.14	71%
Total	0.47	43.2%	0.97	58.9%	1.83	83.9%

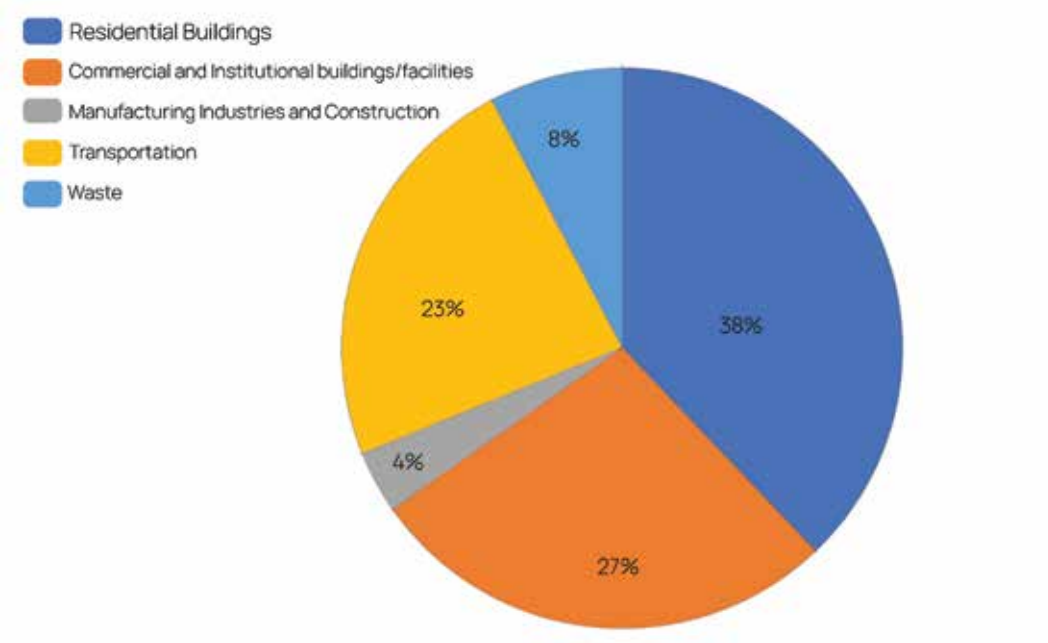


Figure 8.1: Sectoral GHG emissions reduction in Net-Zero Pathway scenario, 2070

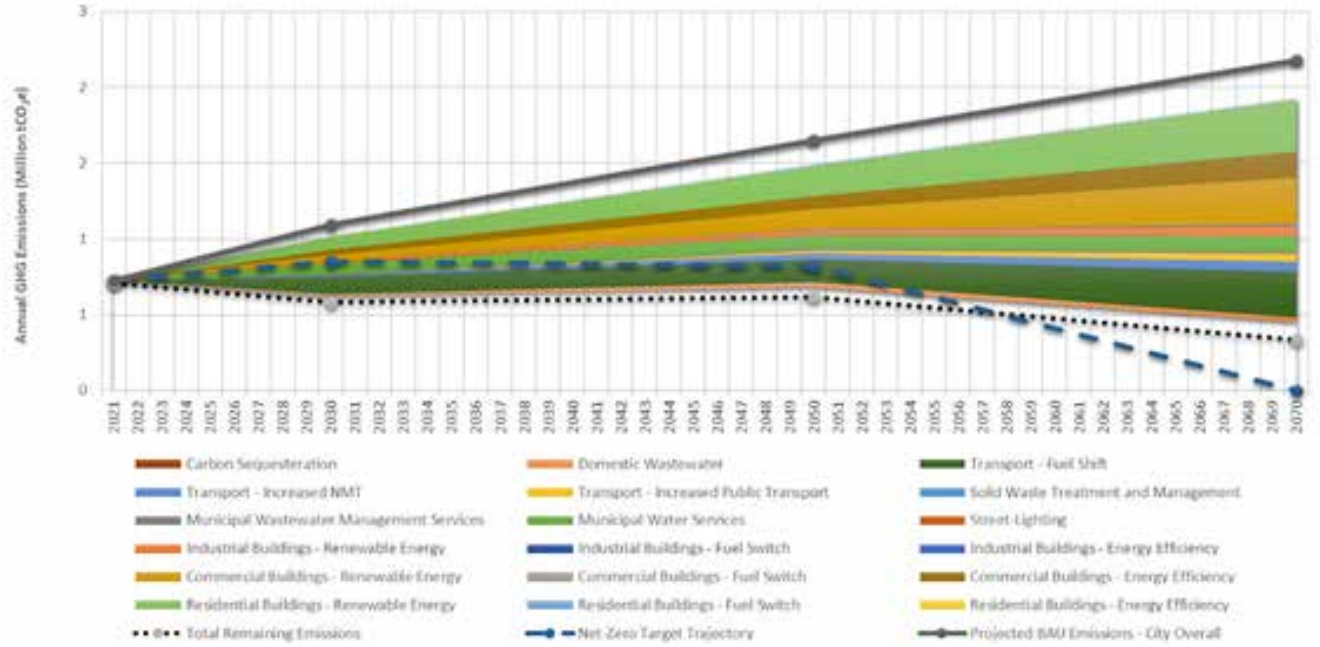


Figure 8.2: GHG emissions mitigation trend for Net-zero Pathway scenario, 2021 to 2070

Residual Emissions in Net-zero Pathway Scenario

Despite the ambitious targets set in Tirunelveli's Net-zero Pathway scenario for achieving an 83.9% reduction in GHG emissions from BAU levels by 2070, residual emissions of 16.1% (0.35 million tCO2e) still need to be addressed. Reducing these residual emissions is crucial for Tirunelveli to achieve net-zero status by 2070. Further reductions can be achieved through interventions such as full grid decarbonisation, nature-based climate solutions, resource circularity, and utilisation of local carbon sinks. For instance, the city's green cover offers significant potential for carbon sequestration. Currently, the city's urban green cover constitutes 25.32% of Tirunelveli's land use (27.5 sq km), translating to a per capita green cover of 49.62 sq m, well above the WHO-recommended 9 sq m per person.

While Tirunelveli has adequate green spaces now, future urban development may alter this balance. According to the Tirunelveli Master Plan 2021, dry agricultural lands, currently accounting for 20.24% of the city's area, are designated for institutional and mixed residential purposes by 2041, indicating a significant reduction in open and green spaces. However, maintaining the current tree cover of 25.32% could sequester up to 0.88 million tCO2e. Thus, preserving and expanding tree cover with native species can significantly enhance the city's carbon sequestration potential and support in achieving its net-zero targets.

Implementing the strategies outlined in this Net-zero CRCAP and achieving net-zero targets will require substantial policy support; enabling regulatory and institutional frameworks; capacity building; and financial support from state, national, and international sources. Periodic reviews of the Net-zero CRCAP are necessary to ensure sustained support and updates to policy, capacity building, climate finance, and other aspects until 100% reduction of BAU GHG emissions is achieved. TCMC commits to collaborating with key departments and stakeholders to realise their net-zero vision ahead of schedule.

8.3 Sectoral Actions and Implementation

Tirunelveli's Net-zero CRCAP outlines 21 strategies across 7 sectors to achieve a vision of net-zero emissions and enhanced climate resilience. These strategies provide a roadmap for sustainable urbanisation that is environmentally responsible, socially equitable, and economically prosperous. Aligned with Tamil Nadu's SAPCC and India's NDCs, the plan aims to reduce climate risks and vulnerabilities while achieving net-zero GHG emissions by 2070. Implementing these actions will enhance resilience to climate risks, conserve resources, ensure energy and water security, reduce municipal energy expenses, and improve public health. Each sector's strategies are integrated with existing plans and schemes to institutionalise climate action in urban governance. Enabling actions provide policy recommendations and guide the design and implementation of climate initiatives.

Climate actions can be prioritised for implementation based on their resilience potential, feasibility, and period of impact realisation. Feasibility is assessed across three parameters: technical, political, and financial. Actions are scored as low, medium, or high feasibility depending on how many of these parameters they meet. The impact realisation period is categorised as short-term (by 2030), medium-term (by 2050), and long-term (by 2070). TCMC and other stakeholders can select climate actions for implementation based on their prioritisation score, feasibility score, and the period for impact realisation. For instance, implementing 100% solid waste segregation, transfer, and processing is a prioritised action with high resilience potential and feasibility, and its impact can be realised in the short term.

8.3.1 Built Environment and Energy

2021

Baseline status

Energy consumption (GJ):
3.42 million GJ (56.9% of total energy consumption)

GHG emissions:
0.47 million tCO2e (64.03% of total GHG emissions)

Key statistics

Sector	Share in Buildings Energy Use (Baseline)	GHG Emissions (tCO2e)
Residential Buildings	65.16	64.84
Commercial and Institutional Buildings	17.93	23.92
Manufacturing Industries and Construction	16.89	11.22

Opportunities and challenges/gaps

UJALA Scheme, ESEAP Scheme, BEE star labelling program and awareness supporting penetration for EE appliances

Tamil Nadu Solar Power Policy (2019) and Tamil Nadu Wind Energy Roadmap (GWEC), supported by GoI, penetrating RE installations

Pradhan Mantri UJJWALA scheme supporting cleaner fuel adoption

Lack of mandates for implementation and enforcement of green buildings through master plans and building development rules, Lack of incentives to builders for adopting green building principles and lack of enforcement of ECBC by state government

Government housing divisions/departments are adopting green principles, but this can be more full-fledged adoption aligned to ECBC

Lack of net metering facility for rooftop solar more than 151 kWp leads to lack of adoption for medium enterprises as the cost of the transformers can be prohibitive

Building Policy and Ongoing Initiatives

National Policy/Programs/Targets:

NDC, India: 50 percent of electric power installed capacity from renewable sources by 2030

Ministry of Power's target to all DISCOMs to achieve 43.3% Renewable Purchase Obligation by 2030

India Cooling Action Plan intends to reduce cooling demand by 20% to 25% (focusing on building envelope design) and cooling energy demand by 25% to 40% by 2038.

Mission LiFE promoting an environmentally conscious lifestyle

NCAP supporting air quality improvement measures, including adoption of cleaner fuel, use of RE, increase in green cover etc.

State and City Level Policy/Programs/Targets

GoTN intends to meet 40% of the consumer category of the total target of 900 MW solar energy target of 2023.

Tamil Nadu Combined Development & Building Rules - 2019 (TNCDBR) promote solar PV installation, solar water heater, green cover etc.

Tirunelveli Master Plan 2021 promotes ground mounted solar in the city's outskirts under local planning area where land is available.

Climate Risk and BAU GHG Emissions Scenario

Residential Buildings	BAU GHG Emissions (Million tCO2e)			Share in overall BAU GHG Emissions (%)		
	2030	2050	2070	2030	2050	2070
Residential Buildings	0.42	0.59	0.73	38.50	35.72	33.57
Commercial and Institutional Buildings	0.20	0.36	0.53	18.53	21.75	24.22
Manufacturing Industries and Construction	0.09	0.17	0.25	8.69	10.20	11.36
Total GHG Emissions from Buildings	0.72	1.12	1.51	65.74	67.70	69.15

Note: The projected emissions for commercial and institutional buildings sector includes emissions from municipal service facilities such as water supply, wastewater, and street-lighting in addition to commercial/private/public buildings.

Climate Risk Status: Medium to High

High surface and air temperature, and related impacts on health due to poor heat resilience

Increase in energy demand, especially for cooling, with growing population and rising temperatures

Urban flooding and water logging risks due to impermeable surface areas in built environment

Increased demand for water and resources

Potential climate resilience impact from identified interventions (Net-zero scenario)

GHG Mitigation Potential and Indicative Cost of Interventions

Particulars	Net-zero Scenario Net-zero Scenario		
	2030	2050	2070
GHG emissions reduction from BAU (%)	35%	54%	79%
Total cost of mitigation actions (Million INR)	10,394	24,823	49,976
Total cost of adaptation actions (Million INR)			
Not estimated			

Climate Resilience Impact

Reduced dependency on grid for energy; high clean power integration

Improved indoor thermal comfort in buildings and enhanced heat resilience

Improved permeable surfaces in the built environment

Reduced fuel consumption in buildings

SDGs

8.3.1.1 Mitigation Strategies for Built Environment and Energy

Target

60% new buildings implement green building principles by 2070.
100% energy efficient lighting and fans in new and existing buildings
Up to 65% energy demand met by RE by 2070

Strategy 1: Encourage use of green building principles to design thermally comfortable and high-performance buildings.

Action 1

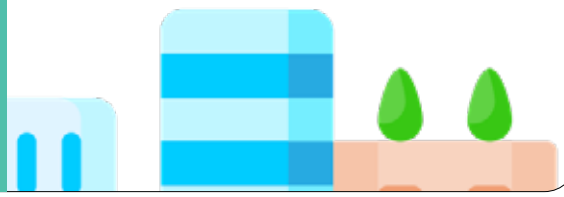
Develop a customised green building policy for Tirunelveli that encourages the development of low-carbon and heat-resilient built environment.

Detailed Targets

Create a green building policy tailored to Tirunelveli's specific building characteristics, climate conditions, and local construction practices, integrating sustainable principles across the entire building lifecycle, including design, construction, operation, and decommissioning.

Action 2

Tirunelveli to adopt green building principles in design and construction of new buildings in line with local policy and national building codes, to conform with ECBC standards



Detailed Targets

Percentage of new buildings to implement green building principles:

Residential:

2030: 20% of new buildings
2050: 40% of new buildings
2070: 60% of new buildings

Commercial & Institutional:

2030: 30% of new buildings
2050: 45% of new buildings
2070: 60% of new buildings

Action 3

Encourage window glazing measures in new and existing residential properties to reduce solar heat ingress

Detailed Targets

Residential:

2030: 25% of buildings
2050: 45% of buildings
2070: 60% of buildings

Commercial & Institutional:

2030: 40% of buildings
2050: 60% of buildings
2070: 80% of buildings

Implementation Entities and Financing Mode

- Town Planning and Engineering Department of TCMC
- Associations of building design consultants and developers
- Green building accreditation agencies like GRIHA, IGBC
- Banks and financial institutions

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high; Short term

Implementation Entities and Financing Mode

- Town Planning and Engineering Department of TCMC
- Associations of building design consultants and developers
- Green building accreditation agencies like GRIHA, IGBC
- Banks and financial institutions

Financing mode:

- Financial incentives by TCMC through building regulations
- Concessional loans by financial institutions for green buildings
- Cost of Green building certification borne by developers or stakeholder departments

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high; Short term

Implementation Entities and Financing Mode

- Town Planning and Engineering Department of TCMC
- Associations of building design consultants and developers
- Green building accreditation agencies like GRIHA, IGBC
- Banks and financial institutions

Financing mode:

- Financial incentives by TCMC through building regulations
- Concessional loans by financial institutions for green buildings
- Cost of Green building certification borne by developers or stakeholder departments

Total Indicative Cost by Timeline

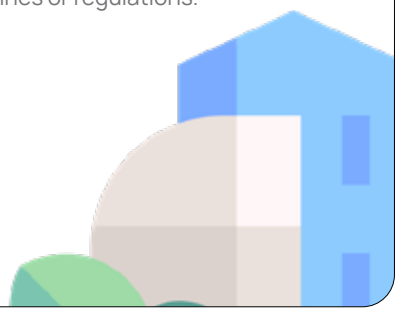
Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high; Mid-term

Action 4

Promote Cool Roofs in new and existing residential properties through dedicated programmes and building guidelines or regulations.



Detailed Targets

Residential:

2030: 25% of buildings
2050: 45% of buildings
2070: 60% of buildings

Commercial & Institutional:

2030: 40% of buildings
2050: 60% of buildings
2070: 80% of buildings

Enabling Actions

Develop tailor-made Green Building Policy to suit the city's building stock and context, and a local implementation plan with long-term goals.

Provide financial incentives and enact by-laws to encourage adoption of Eco-Niwas Samhita for residential buildings and ECBC 2017 for commercial buildings.

Mandate ECBC 2017 compliance for commercial buildings with connected loads exceeding 100 kW and develop a less stringent ECBC 2017 for buildings with lower connected loads, incentivising compliance through tax rebates and FSI benefits.

Conduct energy benchmarking study to understand end-use patterns across building typologies and implement pilot initiatives to understand cost impact of ECBC compliance.

Promote cool roof measures such as white painted or tile roofs, and other sustainable building practices aimed at thermal comfort, EE, and use of sustainable building materials.

Simplify the process for developers to access existing incentives, updating them to better reflect costs and spur adoption.

Pilot net-zero building concepts in municipal infrastructure, public buildings of TCMC and other government agencies, and affordable housing units developed by TNHUDB.

Conduct IEC campaigns in vulnerable communities to promote thermal comfort and cost savings, and provide guidelines for developers and citizens on low and no-cost energy-saving measures during building design and construction to promote building efficiency among all levels of the community.

Implement pilot initiatives in collaboration with relevant authorities to conduct energy audits and implement EE measures in different building typologies.

Collaborative initiatives with key stakeholders such as trade/industrial associations/residential welfare associations to provide low-cost credit for EE measures in collaboration with banks.

Promote green-building rating or other labelling standards for existing and new commercial, institutional, and residential buildings. Target existing mid and large-scale energy intensive commercial entities like shopping malls, academic institutes, hospitals, and hotels to undertake energy audits for energy performance improvement.

Strategy 2: Mandate targeted energy performance measures and green building standards for buildings.

Action 1

Promote adoption of high-energy efficiency appliances – LED Lighting

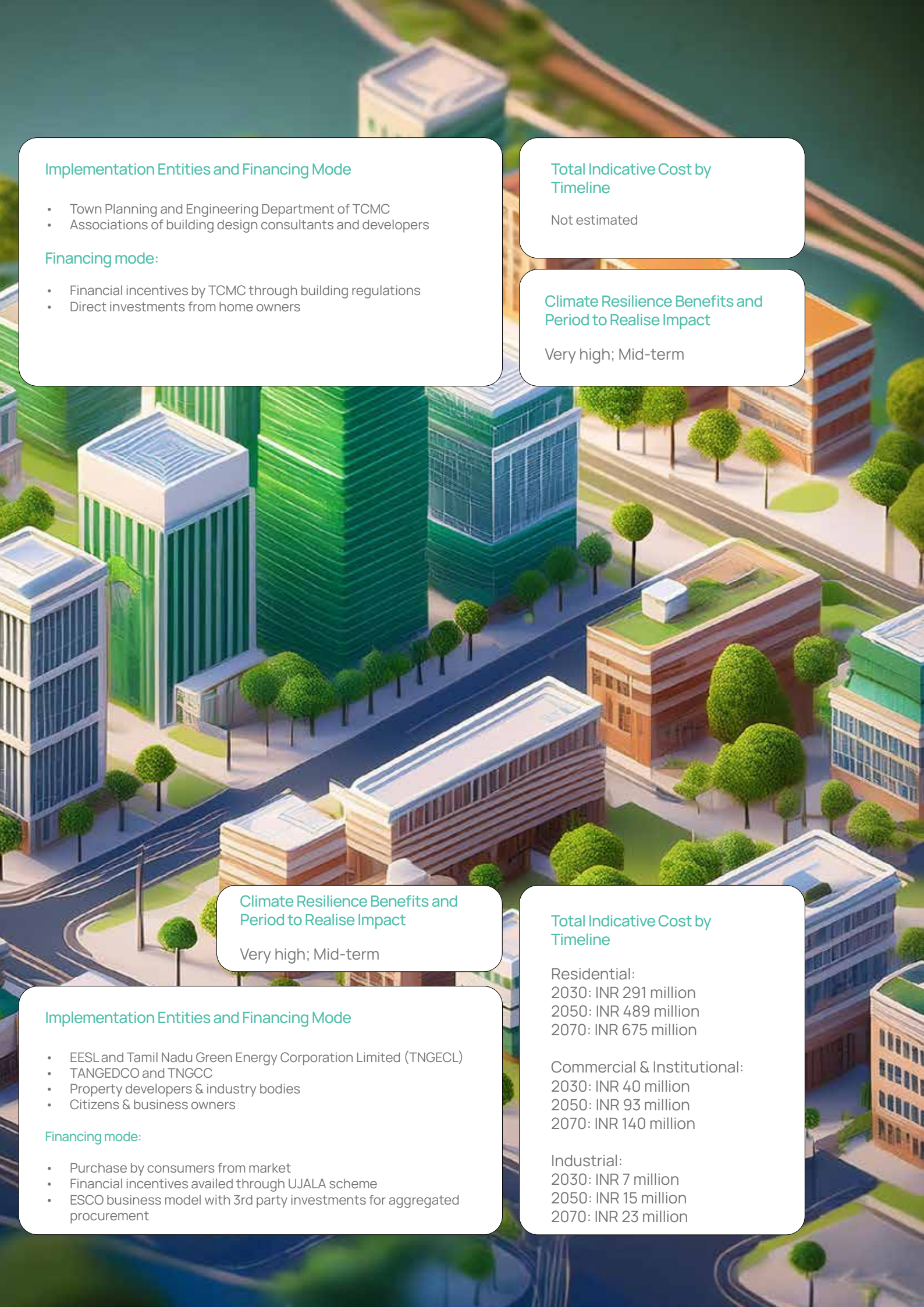
Detailed Targets

Extent of efficient LED lights by sector:

Residential:
2030: 75%
2050: 90%
2070: 100%

Commercial & Institutional:
2030: 80%
2050: 100%
2070: 100%

Industrial:
2030: 80%
2050: 100%
2070: 100%



Implementation Entities and Financing Mode

- Town Planning and Engineering Department of TCMC
- Associations of building design consultants and developers

Financing mode:

- Financial incentives by TCMC through building regulations
- Direct investments from home owners

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high; Mid-term

Climate Resilience Benefits and Period to Realise Impact

Very high; Mid-term

Total Indicative Cost by Timeline

Residential:
2030: INR 291 million
2050: INR 489 million
2070: INR 675 million

Commercial & Institutional:
2030: INR 40 million
2050: INR 93 million
2070: INR 140 million

Industrial:
2030: INR 7 million
2050: INR 15 million
2070: INR 23 million

Implementation Entities and Financing Mode

- EESL and Tamil Nadu Green Energy Corporation Limited (TNGECL)
- TANGEDCO and TNGCC
- Property developers & industry bodies
- Citizens & business owners

Financing mode:

- Purchase by consumers from market
- Financial incentives availed through UJALA scheme
- ESCO business model with 3rd party investments for aggregated procurement

Action 2

Promote adoption of high-energy efficiency appliances – Ceiling Fans

Detailed Targets

Extent of energy efficient BLDC fans by sector:

Residential:
2030: 50%
2050: 80%
2070: 100%

Commercial & Institutional:
2030: 40%
2050: 70%
2070: 100%

Industrial:
2030: 40%
2050: 70%
2070: 100%

Implementation Entities and Financing Mode

- EESL and TNGECL
- TANGEDCO and TNGCC
- Property Developers & industry bodies
- Citizens & business owners

Financing mode:

- Purchase by consumers from market
- Financial incentives availed through UJALA scheme
- ESCO business model with 3rd party investments for aggregated procurement

Action 3

Promote adoption of high-energy efficiency appliances – Refrigerators

Detailed Targets

Extent of efficient refrigerators by sector:

Residential:
2030: 40%
2050: 60%
2070: 85%

Commercial & Institutional:
2030: 50%
2050: 65%
2070: 90%

Implementation Entities and Financing Mode

- EESL and TNGECL
- TANGEDCO and TNGCC
- Property developers & industry bodies
- Citizens & business owners
- Associations of commercial entities

Financing mode:

- Purchase by consumers from market
- ESCO business model with 3rd party investments for aggregated procurement

Action 4

Promote adoption of high-energy efficiency appliances – Energy efficient water pumps in large apartments and residential societies

Detailed Targets

Extent of BLDC/VFD pumps:

Residential:
2030: 40% of pumps
2050: 60% of pumps
2070: 85% of pumps

Implementation Entities and Financing Mode

- TNGECL and TCMC
- BEE and EESL
- Citizens & business owners
- Associations of commercial entities

Financing mode:

- Purchase by consumers directly from market
- ESCO model for EE retrofitting with 3rd party investments for aggregated procurement

Total Indicative Cost by Timeline

Residential:
2030: INR 1,048 million
2050: INR 2,352 million
2070: INR 3,650 million

Commercial & Institutional:
2030: INR 99 million
2050: INR 321 million
2070: INR 695 million

Industrial:
2030: INR 29 million
2050: INR 90 million
2070: INR 190 million

Climate Resilience Benefits and Period to Realise Impact

High, Short-term

Total Indicative Cost by Timeline

Residential:
2030: INR 1,562 million
2050: INR 3,284 million
2070: INR 5,777 million

Commercial & Institutional:
2030: INR 1,149 million
2050: INR 2,762 million
2070: INR 5,800 million

Climate Resilience Benefits and Period to Realise Impact

Medium, Short to mid-term

Total Indicative Cost by Timeline

2030: INR 142 million
2050: INR 298 million
2070: INR 524 million

Climate Resilience Benefits and Period to Realise Impact

Medium, Short to mid-term

Enabling Actions

TCMC to support EESL and TNGECL in expanding LED lighting and super-efficient fans through the UJALA scheme

TCMC will conduct city-wide energy use-benchmarking and develop targeted IEC campaigns to raise awareness about building and appliance EE across building typologies.

Prioritise mid and low-income households for replacing conventional appliances with energy-efficient ones and facilitate affordable credit options for purchasing energy-efficient appliances through collaboration with banks to ensure community wide participation in building energy conservation efforts.

Implement pilot initiatives for energy audits and efficiency measures in municipal infrastructure, public buildings of TCMC and other government agencies, and affordable housing units developed by TNHUDB.

Develop a city-wide Green Public Procurement Policy for all public buildings and facilities in collaboration with the District Collectorate and other key stakeholders.

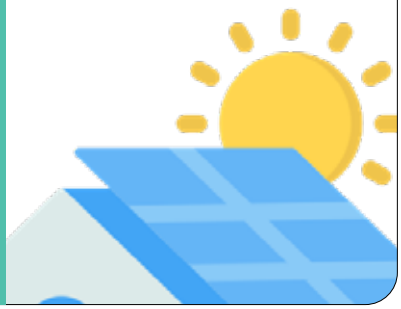
Engage educational institutions in appliance upgrades and awareness campaigns on EE.
Mandate energy-efficient equipment for energy intensive loads such as HVAC systems in the building approval process for commercial and industrial buildings.

Encourage adoption of Building Energy Management Systems (BEMS) in large and energy-intensive public and private buildings to manage energy demand and deploy appropriate EE or RE measures.

Strategy 3: Transition to a clean powered local grid to meet the city's energy demand.

Action 1

Encourage large residential households, and hotels and hospitals with roof availability to use of solar water heaters



Detailed Targets

Percentage of buildings targeted:

Residential:
2030: 10%
2050: 15%
2070: 20%

Targeted no. of hospitals and hotels:
2030: 0.25% (33)
2050: 0.4% (65)
2070: 0.5% (98)

Implementation Entities and Financing Mode

- TCMC & TNGECL
- Consumers, dealers and service providers
- TANGEDCO & DTCP

Financing mode:

- Investment by consumers (hospital & hotel developers)
- Demand aggregation of multiple projects facilitated by TNGECL and TCMC

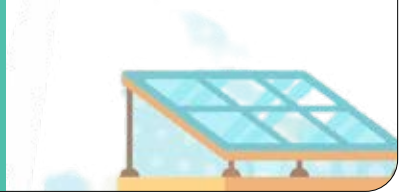
Action 2

Scale up use of RE through:

Decentralised rooftop or ground mounted solar PV plants within the city

Off-site deployment of ground mounted solar PV plants

Purchase of green power from DISCOM



Detailed Targets

Share of building electricity consumption to be met by RE:

Residential:
2030: 20%
2050: 35%
2070: 50%

Commercial & Institutional:
2030: 25%
2050: 45%
2070: 65%

Industrial:
2030: 45%
2050: 60%
2070: 80%

Implementation Entities and Financing Mode

- TCMC, TNGECL, TNERC, TANGECO
- Consumers and service providers such as RESCO companies, RE system vendors
- RWAs and RE industry associations
- Large-scale RE developers

Financing mode:

- Investment by consumers;
- Demand aggregation of multiple projects facilitated by TNGECL
- Sale of carbon credits in voluntary carbon markets (in selected registries)

Total Indicative Cost by Timeline

Residential:
2030: INR 292 million
2050: INR 544 million
2070: INR 828 million

Hotels & Hospitals:
2030: INR 0.57 million
2050: INR 1.1 million
2070: INR 1.66 million

Climate Resilience Benefits and Period to Realise Impact

Very high, Short-term

Total Indicative Cost by Timeline

Residential:
2030: INR 2,233 million
2050: INR 4,893 million
2070: INR 9,720 million

Commercial & Institutional:
2030: INR 1,345 million
2050: INR 4,354 million
2070: INR 9,432 million

Industrial:
2030: INR 408 million
2050: INR 930 million
2070: INR 1,824 million

Climate Resilience Benefits and Period to Realise Impact

Very high; Mid-term

Enabling Actions

Conduct detailed mapping of rooftop areas in the city to identify potential sites for solar PV deployment and amend building regulations in collaboration with DTCP to mandate rooftop solar PV installation on buildings with significant rooftop space.

Collaborate with DTCP to provide financial incentives such as property tax rebates to promote RE adoption.

Assist TNERC and TANGEDCO in revising net-metering policies and feed-in tariffs to incentivise small-scale prosumers to invest in rooftop solar PV.

Facilitate consumers and support TANGEDCO in demand aggregation to reduce capital costs for solar PV and wind power plants for smaller consumers and RE integration in cluster development initiatives.

Collaborate with TNGECL and TANGEDCO to promote group captive models for residential, commercial, and industrial consumers with limited land availability, enabling access to green power at low cost.

TNGECL/TANGEDCO to enable open access for green power purchase by all commercial and industrial consumers to achieve net-zero emissions.

Encourage partnerships between large commercial/ industrial entities in the city and DISCOMS for off-site RE plant deployment with BESS and wheeling of power, supporting net-zero goals and RPO obligations of DISCOMs.

Identify carbon credit projects, undertake feasibility assessments, and register for carbon credits as individual or group projects (applicable for selected carbon registries).

Action 1

Shift towards cleaner fuel

Detailed Targets

Extent of shift to renewable-based electricity from LPG to meet energy requirements by sector:

Residential:
2050: 5% of LPG consumption
2070: 10% of LPG consumption

Commercial:
2050: 10% of LPG consumption
2070: 15% of LPG consumption

Implementation Entities and Financing Mode

- TANGEDCO and TNGECL
- TCMC, TNPCB, citizens, business owners
- RWAs, Commercial associations of commercial entities

Financing mode:

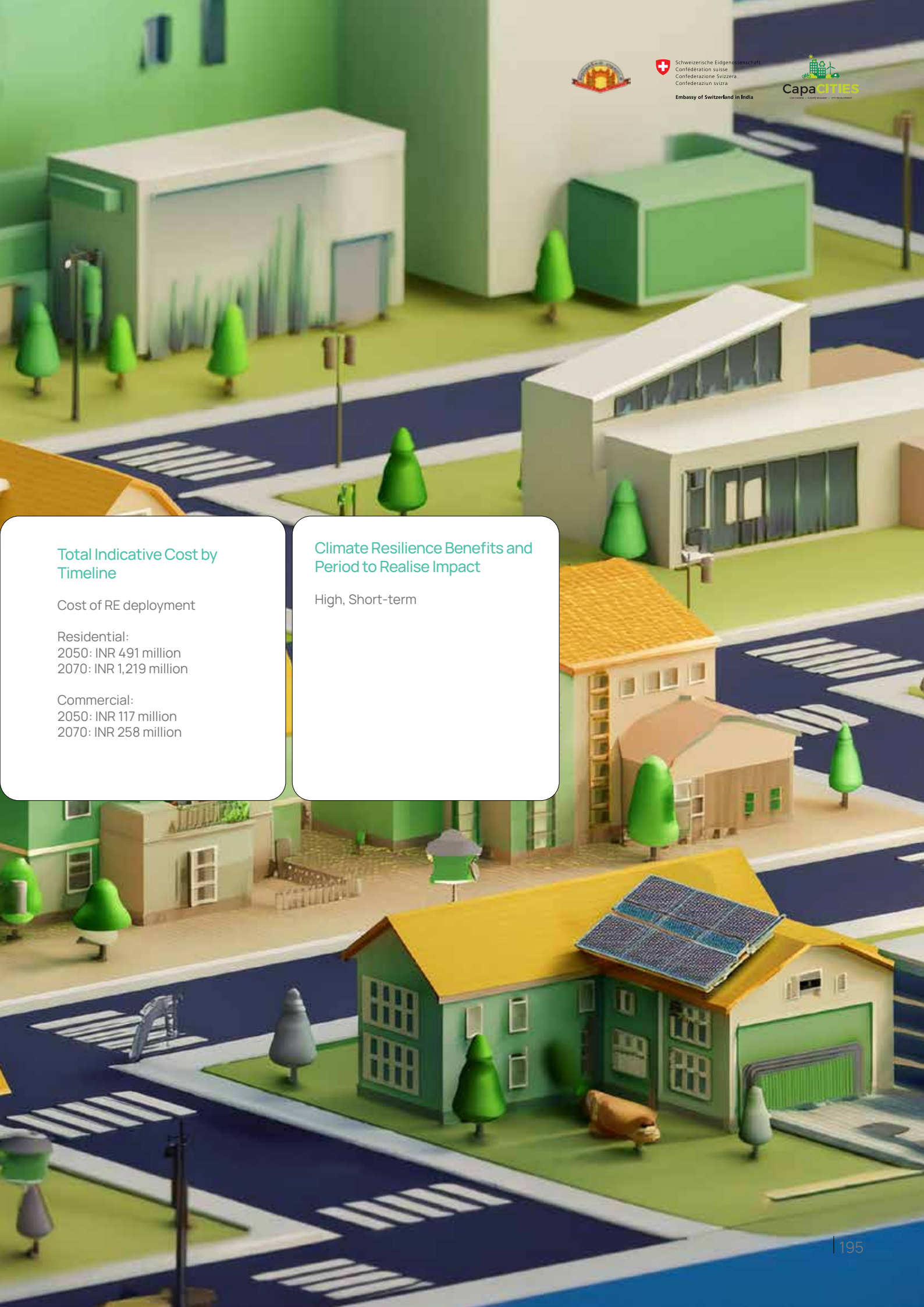
- Consumer investing in electricity connection and use
- Incentives by TCMC/ TNPCB for fuel switch

Enabling Actions

Provide financial incentives to small-scale commercial entities to switch from LPG to renewable electricity and facilitate demand aggregation to support creation of a substantial consumer base.

Focus on large commercial consumers with high fuel consumption, such as those in the hospitality and healthcare sectors, to transition towards renewable electricity.

Collaborate with TNPCB to advocate for the use of renewable electricity as fuel for commercial purposes.



Total Indicative Cost by Timeline

Cost of RE deployment

Residential:
2050: INR 491 million
2070: INR 1,219 million

Commercial:
2050: INR 117 million
2070: INR 258 million

Climate Resilience Benefits and Period to Realise Impact

High, Short-term

8.3.1.2 Adaptation Strategies for Built Environment and Energy

Target

Transition to an energy efficient and heat resilient city by adopting low-emission strategies for the built environment.

Strategy 1: Promote green building concepts to mitigate urban heat risk.

Action 1

Develop a cool roof program for the city, with focus on heat vulnerable areas on eastern part of city, and pilot cool roof initiatives in public buildings anad social housing.

Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:

- Encourage continued use of traditional lime-based paint for the older building stock in old town areas.
- Propose cool roof measures, use of building materials like Autoclaved Aerated Concrete (AAC) blocks and high Solar Reflectance Index (SRI) paints to improve thermal comfort in public buildings and social housing.
- Monitor air temperatures across multiple locations to provide heat alerts.
- Incentivise and promote city-wide cool roof program; Priority focus on low income areas in eastern part of city which are more prone to heat risks

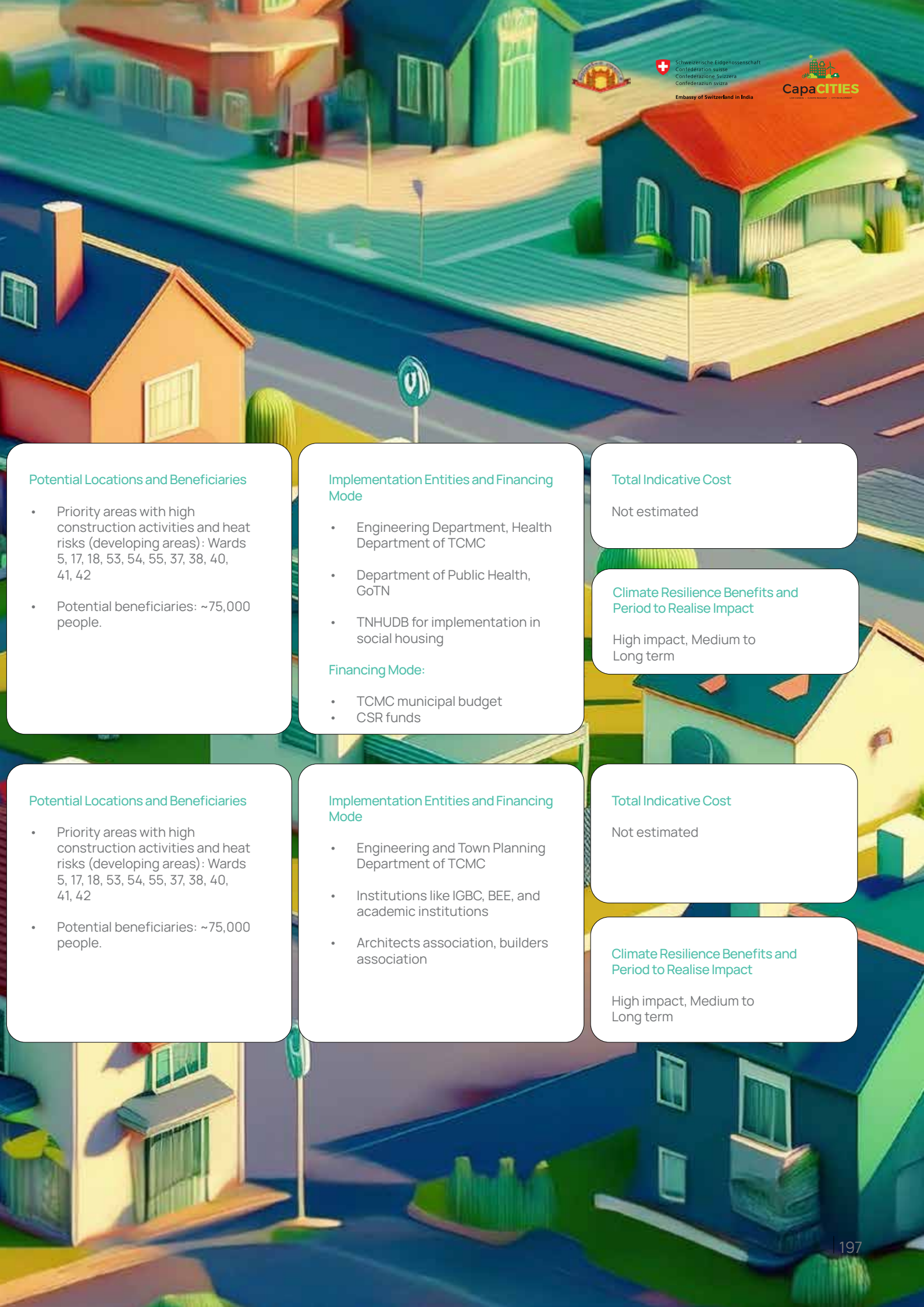
Action 2

Promote adoption of sustainable vernacular architecture, green building principles and heat-resistant building materials for building design and construction to increase heat resilience of the city (including for affordable housing)

Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:

- Increase the number of buildings under green building certification and undertake improvement plans to increase certification grade.
- Pilot green building development in new public buildings built by TCMC.
- Collaborate with TNPWD and DTCP to develop all public buildings in city as green buildings.
- Provide training on green building principles for professionals and skilled labour in construction sector through builder associations and academic institutions.



Potential Locations and Beneficiaries

- Priority areas with high construction activities and heat risks (developing areas): Wards 5, 17, 18, 53, 54, 55, 37, 38, 40, 41, 42
- Potential beneficiaries: ~75,000 people.

Implementation Entities and Financing Mode

- Engineering Department, Health Department of TCMC
- Department of Public Health, GoTN
- TNHUDB for implementation in social housing

Financing Mode:

- TCMC municipal budget
- CSR funds

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Medium to Long term

Potential Locations and Beneficiaries

- Priority areas with high construction activities and heat risks (developing areas): Wards 5, 17, 18, 53, 54, 55, 37, 38, 40, 41, 42
- Potential beneficiaries: ~75,000 people.

Implementation Entities and Financing Mode

- Engineering and Town Planning Department of TCMC
- Institutions like IGBC, BEE, and academic institutions
- Architects association, builders association

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Medium to Long term

Action 3

Incentivise adoption of green building principles and green building rating certification.

Existing Scenario/Proposed Initiatives and Actions

- Mandate all new public buildings to be green building certified.
- Encourage private buildings to achieve green building certification through builder associations.
- Build awareness on green building certification process for private buildings among building developers and offer incentives.

Potential Locations and Beneficiaries

- Upcoming buildings in developing areas of the city
- Priority areas with high construction activities (developing areas): Wards 5, 17, 18, 37, 38, 39, 40, 41, 50, 51, 52, 53, 54, 55
- City wide replication

Action 4

Promote vertical and roof top gardening to decrease surface temperature.

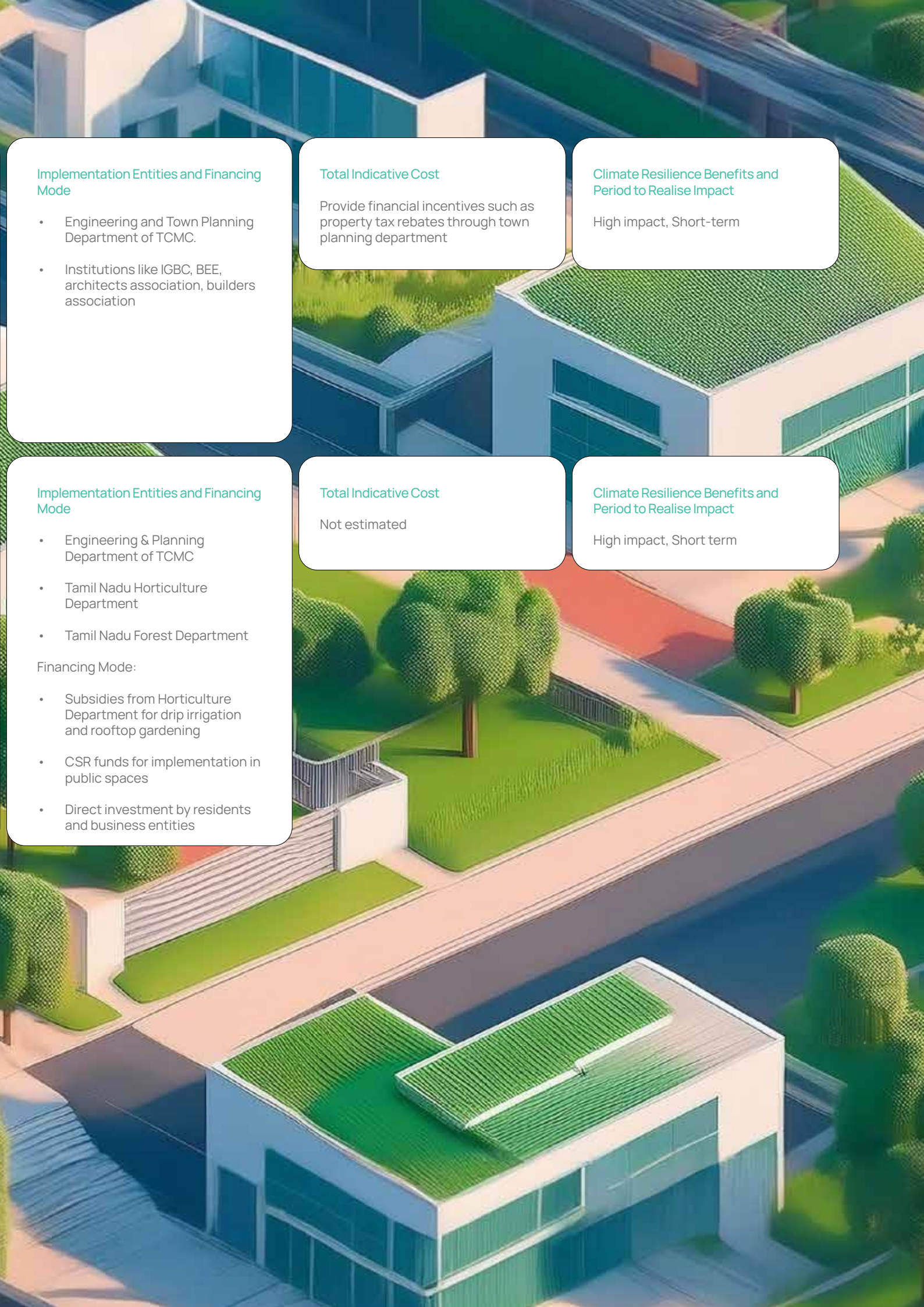
Existing Scenario/Proposed Initiatives and Actions

Proposed Action:

- Provide financial support to residents and commercial entities for implementation of vertical and roof top gardening.
- Implement vertical gardening in public places and infrastructure to improve aesthetics and to keep structures cooler.

Potential Locations and Beneficiaries

- Residential and commercial properties especially in high built-up areas vulnerable to heat risks: Wards 10, 11, 12, 17, 30, 40, 41, 42, 50, 53, 54, and 55
- All public buildings and flyovers across the city



Implementation Entities and Financing Mode

- Engineering and Town Planning Department of TCMC.
- Institutions like IGBC, BEE, architects association, builders association

Total Indicative Cost

Provide financial incentives such as property tax rebates through town planning department

Climate Resilience Benefits and Period to Realise Impact

High impact, Short-term

Implementation Entities and Financing Mode

- Engineering & Planning Department of TCMC
- Tamil Nadu Horticulture Department
- Tamil Nadu Forest Department

Financing Mode:

- Subsidies from Horticulture Department for drip irrigation and rooftop gardening
- CSR funds for implementation in public spaces
- Direct investment by residents and business entities

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short term

8.3.2 Transportation

2021

Baseline status

Energy consumption (GJ):
2.59 million GJ (43.01% of total energy consumption)

GHG emissions:
0.19 million tCO2e (26.63% of total GHG emissions)

Opportunities and challenges/gaps

According to the urban public transport fleet standard of 0.6 buses/1,000 population, the city's bus fleet is sufficient but requires more buses to meet growing demands and to increase shift to public transport, as per Tirunelveli Comprehensive Mobility Plan. All new buses to be procured can be E-buses.

Lack of integration between public transport modes and poor last mile connectivity along public transport routes; IPT modes are expensive and NMT infrastructure is lacking.

Significant increase in private vehicles, especially tow-wheelers in the city

Lack of on and off-street parking facilities and encroachment of roads leading to traffic congestion

Existing policy and ongoing initiatives

National Policy/Programs/Targets:

GoI intends for EV sales penetration of 30% for private cars, 70% for commercial vehicles and 80% for two and three-wheelers.

National Electric Mobility Mission Plan - Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME II). Tamil Nadu has applied for charging infrastructure under the FAME II program and is awaiting sanction.

Voluntary Vehicle-Fleet Modernisation Program (V-VMP) – A guide towards setting up a vehicle scrappage ecosystem

State and City Level Policy/Programs/Targets

Tamil Nadu State EV Policy 2023
TNSTC to procure 3,500 buses including 500 E-buses by 2024

City Policy/Program/Targets:

Conversion of SWM collection vehicles into Battery Operated Vehicles (BOV)

EV charging in TCMC SWM unit offices for charging of BOVs

Climate Risk and BAU GHG Emissions Scenario

Residential Buildings	BAU GHG Emissions (Million tCO2e)			Share in overall BAU GHG Emissions (%)		
	2030	2050	2070	2030	2050	2070
Transport	0.27	0.38	0.47	24.7	22.91	21.53

Climate Risk Status: High risk during high temperature and high intensity rainfall

Increased use of private vehicles, especially two wheelers, and increase in traffic congestion particularly during peak hours and festival days

Pedestrians, cyclists, and people using two wheelers are most vulnerable to extreme heat risks, particularly at major traffic junctions and in the eastern part of city with high surface temperatures.

Extreme rainfall events impact road network and smooth flow of traffic, especially in the 17 key traffic junctions many of which are in urban flood risk zones.

Potential climate resilience impact from identified interventions (Net-zero scenario)

GHG Mitigation Potential and Indicative Cost of Interventions

Particulars	Net-zero Scenario Net-zero Scenario		
	2030	2050	2070
GHG emissions reduction from BAU (%)	49	57	91
Total cost of mitigation actions (Million INR)	NA		
Total cost of adaptation actions (Million INR)	INR 1,567 million by 2070		

Climate Resilience Impact

Improved public transport services and NMT and decreasing use of private vehicles

Integrated mobility giving accessibility across all parts of city

Reduced traffic congestion and improved air quality

SDGs

3 GOOD HEALTH AND WELL-BEING
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION

8.3.1.2 Adaptation Strategies for Built Environment and Energy

Goal

Encourage development of zero-emission transport infrastructure and adoption of clean mobility options.

Target

10% motorised trips shift to NMT and 8% trips shirt to public transport by 2070.

90% vehicles are electric and renewable powered by 2070.

Strategy 1: Develop NMT (biking and walking) infrastructure and improve efficiency of public transit.

Action 1

Promote use of non-motorised mobility, especially for short trips, and develop NMT infrastructure across Tirunelveli.

Sub-action:

Develop plan for improving last-mile connectivity with focus on NMT.

Detailed Targets

Sub-actions

Shift in passengers from private transport to non-motorised mobility such as walk and bicycles:
2030: 5%
2050: 8%
2070: 10%

Proposed Actions:

Encourage bicycles for last mile connectivity from key public transit nodes such as bus stands by providing free parking facilities and building cycle tracks.

Develop NMT infrastructure in old town areas without access to public transport.

Build bicycle parking facilities in public buildings and public parking zones.

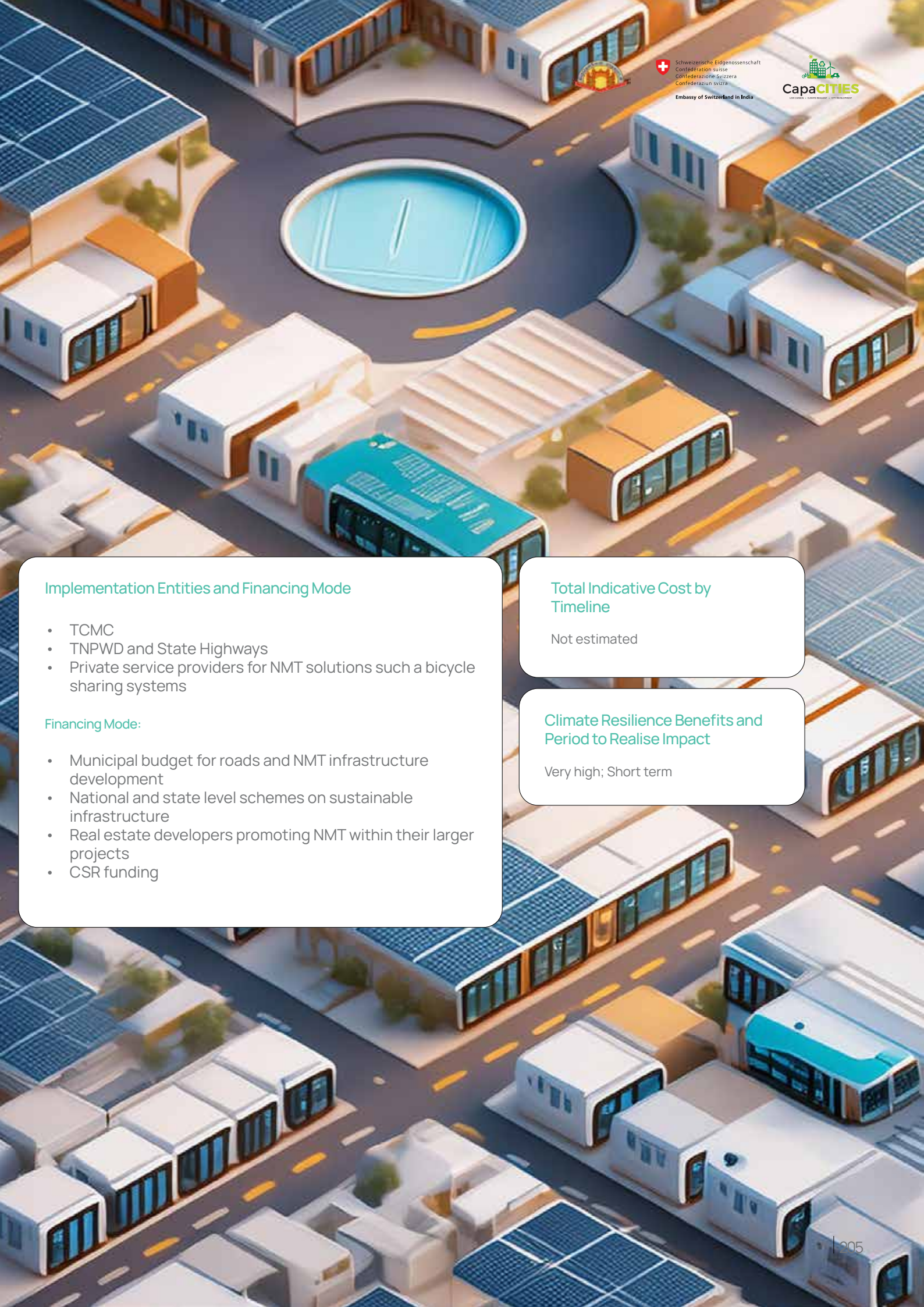
Enabling Actions

Promote cycling by implementing dedicated cycle tracks and developing green mobility zones in the congested old town areas of Tirunelveli.

Implement public bicycle sharing scheme in priority areas to connect offices, academic institutions, public spaces, public transit stations, and major bus stops for short trips and last mile connectivity.

Mandate paved sidewalks for pedestrian movement in newly developed streets and roads and increase paved footpaths in roads with unpaved footpaths along its shoulders.

Adoption of street design standards and measures to ensure safe walking and bicycling



Implementation Entities and Financing Mode

- TCMC
- TNPWD and State Highways
- Private service providers for NMT solutions such a bicycle sharing systems

Financing Mode:

- Municipal budget for roads and NMT infrastructure development
- National and state level schemes on sustainable infrastructure
- Real estate developers promoting NMT within their larger projects
- CSR funding

Total Indicative Cost by Timeline

Not estimated

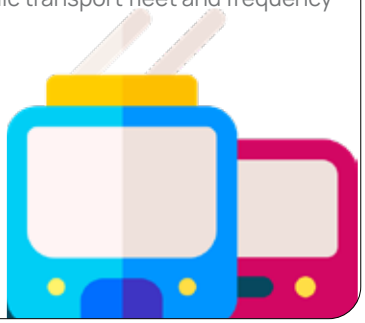
Climate Resilience Benefits and Period to Realise Impact

Very high; Short term

Action 1

Promote use of public transport for mobility needs of citizens.

Sub-actions:
- Increase public transport connectivity and bus stops.
- Increase public transport fleet and frequency of trips.



Detailed Targets
Sub-actions

Shift in passengers from private transport to public transport:
2030: 3%
2050: 5%
2070: 8%

Proposed Actions:

Identify new routes and develop smart bus stops integrated to a traffic management system.

Modernise all existing bus stops and build bicycle parking facilities.

Increase bus fleet to cater to new routes or partner with private transport service providers.

Enabling Actions

Enhance public transport ridership by implementing IoT based public transport management system for user-friendly parking and ticketing system, monitoring ridership and service performance of public transport.

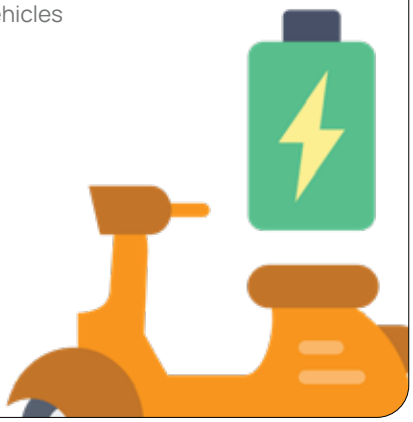
Collaborate with IPT operators' associations to rationalise fares and enhance integration of IPT with public transit stations and major bus stops for improved last-mile connectivity.

Improve coverage, and connectivity of public bus service for higher ridership, either by developing or improving road network, or by deploying smaller buses viable to be run along smaller roads in high density locations.

Strategy 2: Encourage adoption of low-emission mobility options and development of RE powered transport infrastructure.

Action 1

Shift to electric private and commercial passenger vehicles



Detailed Targets & Sub-actions

Share of EVs and electricity demand for EV charging met by renewables:

2030: 30% cars, 80% commercial vehicles, 80% two & three wheelers (30% RE powered)

2050: 50% cars, 80% commercial vehicles, 80% two & three wheelers (50% RE powered)

2070: 90% cars, 90% commercial vehicles, 90% two & three wheelers (70% RE powered)

Action 2

Build EV charging infrastructure in TCMC owned public buildings and parking facilities.

Detailed Targets & Sub-actions

Proposed Actions:

Pilot EV charging stations for bikes and cars in the 5 existing multi-level car and two-wheeler parking facilities.

Build EV charging stations at least for bikes in the TCMC main administrative building and 3 zonal offices with ample parking space.

Implementation Entities and Financing Mode

- TCMC, TNSTC
- Traffic Police Department
- IPT associations and private transport service providers

Financing Mode:

- Funding from TNSTC, Commissionerate of Transport and Road Safety
- TCMC municipal budget
- Tamil Nadu Green Climate Fund (TNGCF)
- Private bus operators investing in bus fleet for access to new routes

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, mid-term

Implementation Entities and Financing Mode

- TANGEDCO, TNGECL
- TNSTC, industries department, TIDCO
- IPT associations
- Technology/service providers for EV charging and RE
- Banks and financial institutions

Financing Mode:

- Aggregated EV procurement for fleet operators from market
- Tamil Nadu State EV policy for subsidies
- FAME II scheme
- PPP mode with private investment for charging infrastructure
- Direct consumer financing
- Low cost credit for EV purchase

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short to mid-term

Implementation Entities and Financing Mode

- TCMC
- TANGEDCO
- Technology/service providers for EV charging and RE

Financing Mode:

- TCMC budget
- CSR funding

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Action 3

Promote adoption of EVs by IPT operators and develop public EV charging infrastructure.

Detailed Targets & Sub-actions

Deploy EV charging infrastructure near dedicated auto and taxi stands.

Develop EV charging infrastructure in key public transit nodes, especially in the 3 bus stands and 4 railway stations.)

Action 4

100% electrification of Tirunelveli's public bus fleet and RE integration in E-bus charging

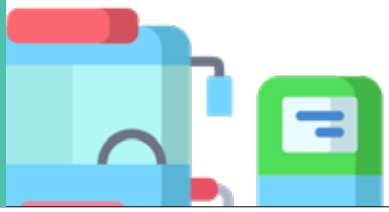
Detailed Targets & Sub-actions

Number of new E-buses required to cater to public transit demand:

No specific target set by GoTN

Action 5

Develop solar powered E-bus charging stations across Tirunelveli for public transport fleet.



Detailed Targets & Sub-actions

Pilot rooftop-solar PV powered E-bus charging infrastructure in bus depots and bus stands.

Build solar powered opportunity charging stations in peripheral areas of the city with land availability.

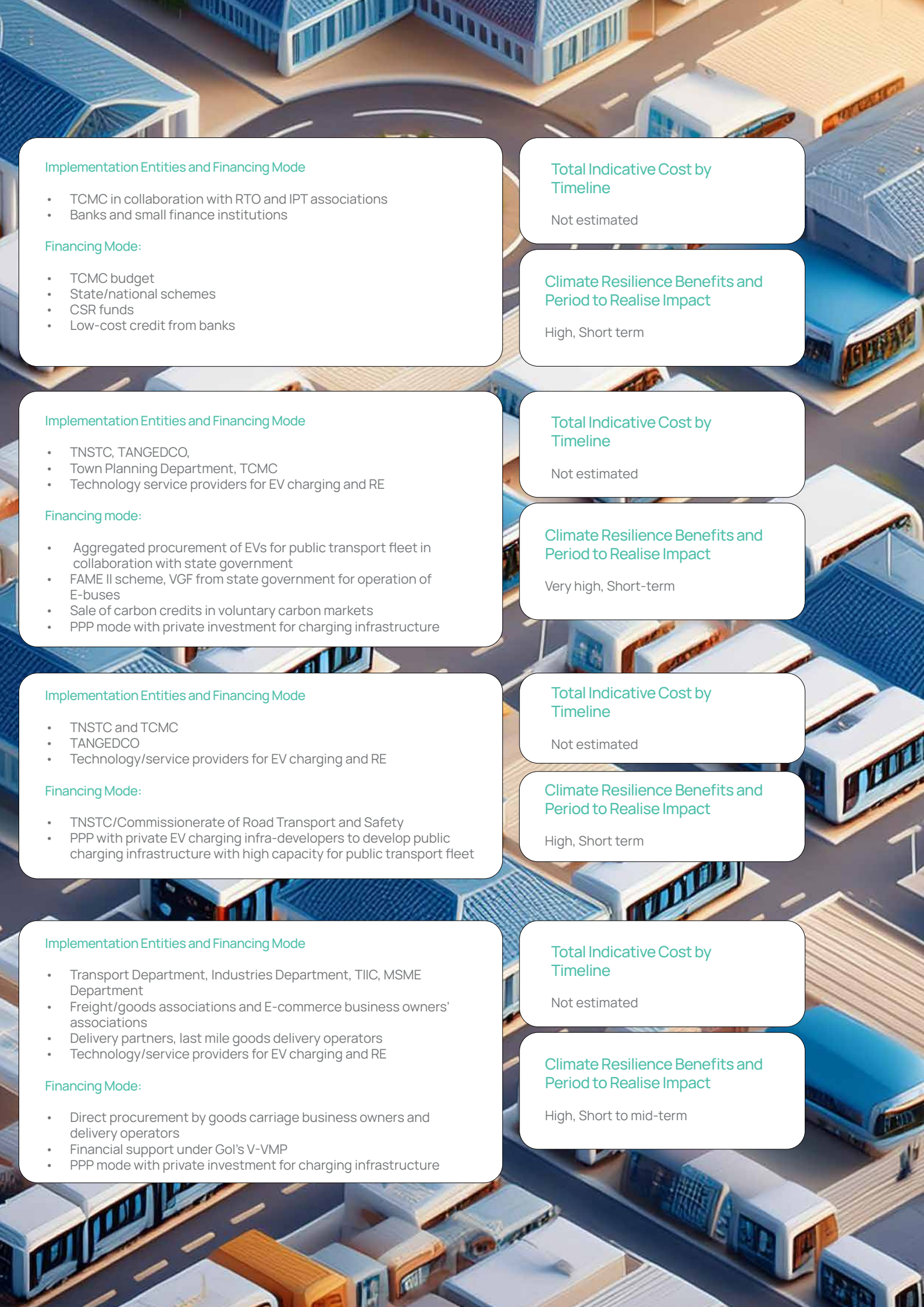
Action 6

Promote electrification of E-commerce service delivery fleet and freight

Detailed Targets & Sub-actions

Share of EVs and electricity demand for charging met by renewables:

2030: 80% light freight vehicles; 40% medium and heavy freight vehicles (30% RE powered)
2050: 90% light freight vehicles; 60% medium and heavy freight vehicles (50% RE powered)
2030: 90% light freight vehicles; 80% medium and heavy freight vehicles (70% RE powered)



Implementation Entities and Financing Mode

- TCMC in collaboration with RTO and IPT associations
- Banks and small finance institutions

Financing Mode:

- TCMC budget
- State/national schemes
- CSR funds
- Low-cost credit from banks

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Implementation Entities and Financing Mode

- TNSTC, TANGEDCO,
- Town Planning Department, TCMC
- Technology service providers for EV charging and RE

Financing mode:

- Aggregated procurement of EVs for public transport fleet in collaboration with state government
- FAME II scheme, VGF from state government for operation of E-buses
- Sale of carbon credits in voluntary carbon markets
- PPP mode with private investment for charging infrastructure

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high, Short-term

Implementation Entities and Financing Mode

- TNSTC and TCMC
- TANGEDCO
- Technology/service providers for EV charging and RE

Financing Mode:

- TNSTC/Commissionerate of Road Transport and Safety
- PPP with private EV charging infra-developers to develop public charging infrastructure with high capacity for public transport fleet

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Implementation Entities and Financing Mode

- Transport Department, Industries Department, TIIC, MSME Department
- Freight/goods associations and E-commerce business owners' associations
- Delivery partners, last mile goods delivery operators
- Technology/service providers for EV charging and RE

Financing Mode:

- Direct procurement by goods carriage business owners and delivery operators
- Financial support under GoI's V-VMP
- PPP mode with private investment for charging infrastructure

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short to mid-term

Enabling Actions

Develop a locally tailored e-mobility plan outlining supportive policies, regulations, and guidelines for electric mobility and charging infrastructure deployment.

Develop public and private EV charging infrastructure and create green mobility zones in the city to promote e-mobility.

Implement policy interventions at the state level, particularly through the Commissionerate of Transport and Road Safety, to facilitate the transition to EVs.

Collaborate with state government departments to offer incentives to encourage EV adoption while implementing measures to disincentivise the use of conventional vehicles in the city with support from Traffic Police Department and RTO.

Develop a comprehensive plan for EV charging infrastructure, encompassing fast-charging stations, residential and workplace charging facilities, and the expansion of public charging options.

Pilot RE powered EV charging solutions with a focus on prioritising public buses and large commercial vehicle fleets. Scale-up RE integration in charging network through on-site or off-site deployments.

Integrate EV infrastructure planning with proposed transport corridors, road networks, and designated zones to ensure seamless connectivity.

Support planning department to mandate provision of EV charging in public and private buildings and infrastructure through building regulations.

Strategy 3: Integrated planning and development of transport infrastructure and adoption of smart traffic management systems

Action 1

Enhance road network and improve road infrastructure to decongest arterial roads and major traffic junctions.

Detailed Targets & Sub-actions

Develop or support development of road network as per Master Plan 2021 to decongest traffic in arterial roads and traffic junctions such as SN High Road, Nainarkulam Road, Town Arch junctions, Thondar Sannathi, Murugankurichi Junction, and Tiruchendur Road.

Improve road infrastructure by making them pothole free and develop pedestrian/bicycle friendly roads.

Action 2

Implement an automated traffic management system based at ICCC and traffic surveillance cameras.

Detailed Targets & Sub-actions

Adopt IoT based traffic management system for efficient management of traffic in the city.
Implement parking management measures, including IoT based parking management system in public parking zones and facilities.
Support Traffic Police Department in traffic management actions such as streamlining of freight movement, increasing traffic surveillance network etc.

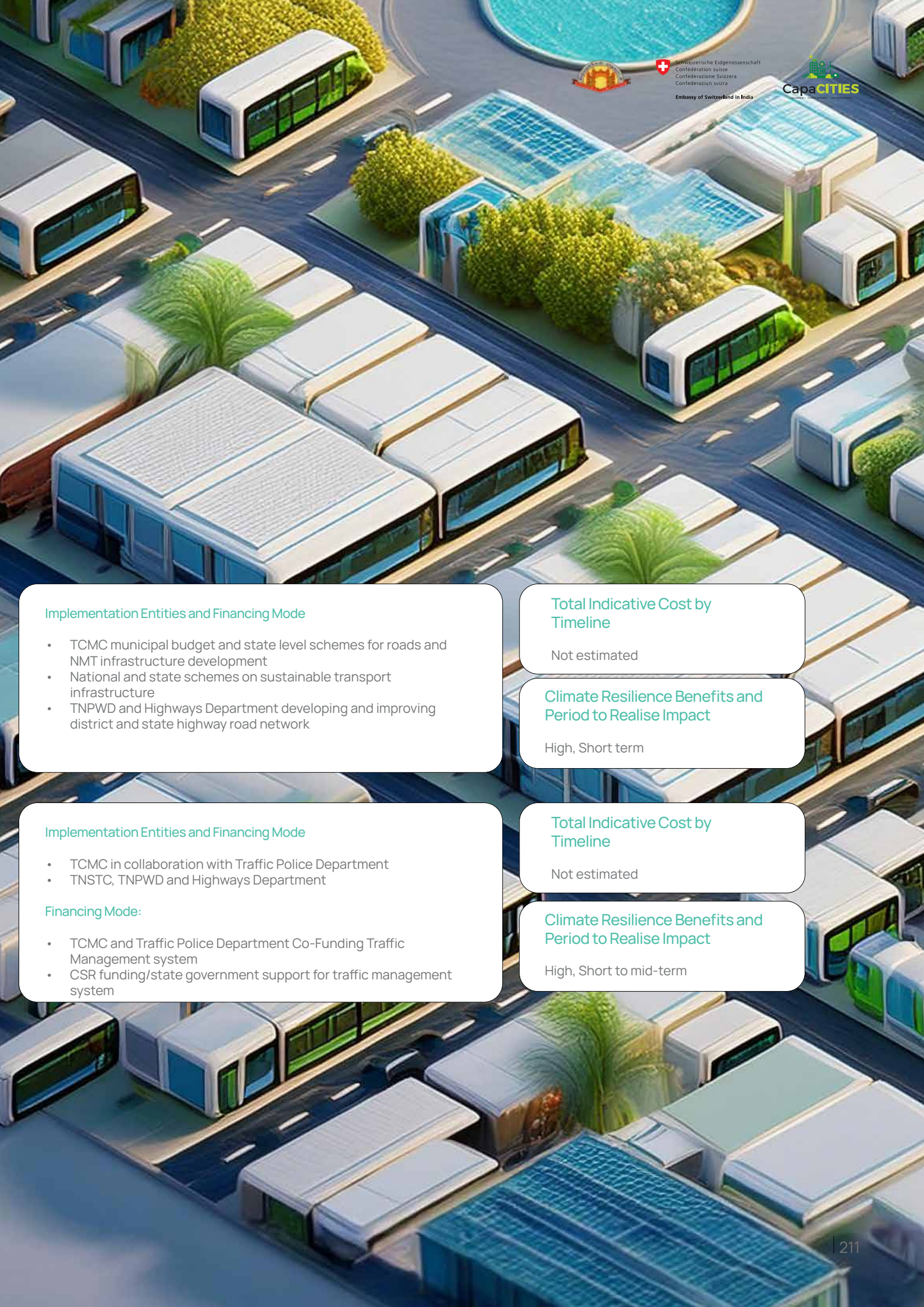
Enabling Actions

Preparation of parking policy and vendor policy to reduce traffic congestion due to unauthorised paring and encroachments

Adopt IoT based intelligent traffic management systems to optimise traffic, public transport, and parking.

Implement parking management measures to develop off-street parking facilities, IPT friendly road infrastructure and parking regulation identified specific to roads/areas.

Regulate freight movement and develop infrastructure to restrict heavy vehicle movement in the city. Develop freight management plan based on Tirunelveli's CMP to integrate urban freight into transport and land-use planning.



Implementation Entities and Financing Mode

- TCMC municipal budget and state level schemes for roads and NMT infrastructure development
- National and state schemes on sustainable transport infrastructure
- TNPWD and Highways Department developing and improving district and state highway road network

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Implementation Entities and Financing Mode

- TCMC in collaboration with Traffic Police Department
- TNSTC, TNPWD and Highways Department

Financing Mode:

- TCMC and Traffic Police Department Co-Funding Traffic Management system
- CSR funding/state government support for traffic management system

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short to mid-term

8.3.3 Water Supply

2021

Baseline status

GHG emissions:
12,984 tCO2e (70.84% of total GHG municipal emissions)

Key statistics:
1) Coverage: 90% water supply and distribution network coverage, 2) Daily Water Supply: 68.58 MLD @100 LPCD, 3) NRW: 25%

Opportunities and challenges/gaps

Dependence on the lone source, Thamirabarani River, for water supply

High dependence on groundwater to meet water demand, and unregulated extraction of groundwater from private wells and borewells

Areas without water supply coverage and poor water distribution network efficiency

Lack of periodic de-siltation and maintenance of water bodies managed by TCMC

Illegal connections, leakage in pipelines and other challenges in water distribution leading to inadequate water pressure, and limited/no water supply in specific areas of network

Existing policy and ongoing initiatives

24X7 water supply pilot in selected areas of city

Rejuvenation of lakes in the city under AMRUT 2.0 for improving storage, bund strengthening and to prevent encroachments

Water supply and distribution network augmentation under 50 MLD Ariyanayagipuram water supply scheme, and 10 MLD Murappanadu water supply scheme

Climate Risk and BAU GHG Emissions Scenario

Residential Buildings	BAU GHG Emissions (Million tCO2e)			Share in overall BAU GHG Emissions (%)		
	2030	2050	2070	2030	2050	2070
Waters Supply	0.02	0.03	0.03	1.96%	1.62%	1.39%

Climate Risk Status: High risk from elevated temperatures, especially during March to May and high intensity rainfall between October to December

High water demand during extreme heat events and reduced flow of water in Thamirabarani River, especially in summer months after drought years

Extreme rainfall events can impact water supply network and cause issues such as damage to water supply network and mixing with stormwater. This could also lead to public health issues such as outbreak of cholera and jaundice.

Potential climate resilience impact from identified interventions (Net-zero scenario)

GHG Mitigation Potential and Indicative Cost of Interventions

Particulars	Net-zero Scenario Net-zero Scenario		
	2030	2050	2070
GHG emissions reduction from BAU (%)	28%	43%	60%
Total cost of mitigation actions (Million INR)	NA		
Total cost of adaptation actions (Million INR)	INR 3,658 million		

Climate Resilience Impact

Clean energy for operating water supply infrastructure reduces impact of emissions from energy intensive municipal water supply sector.

Ensure equitable and safe drinking water access for everyone, highlighting the essential nature of water security.

Revitalise water bodies to reduce urban heat island effects, mitigate flooding, augment groundwater recharge, and enhance ecosystem health.

Adopt data-driven decision-making, ensuring policies and initiatives are guided by accurate insights for improved urban water resource management.

SDGs

8.3.3.1 Mitigation Strategies for Water Sector

Goal

Encourage development of zero-emission transport infrastructure and adoption of clean mobility options.

Target

90% adoption of energy-efficient equipment for water supply and 40% energy demand to be met by RE sources.

Reduce NRW to 15% by 2050 and 10% by 2070.

Strategy 1: Equip water supply network with energy efficient systems powered by RE.

Action 1

Promote EE in water pumping.

Detailed Targets & Sub-actions

2030: 40% of existing pumps
2050: 60% of existing pumps
2070: 90% of existing pumps

Implementation Entities and Financing Mode

- Engineering Department, TCMC

Financing Mode:

- Municipal budget
- ESCO model with private sector investment

Action 2

Utilise solar and wind power in water supply facilities with electricity connections.

Detailed Targets & Sub-actions

Estimated capacity/size:
Solar:

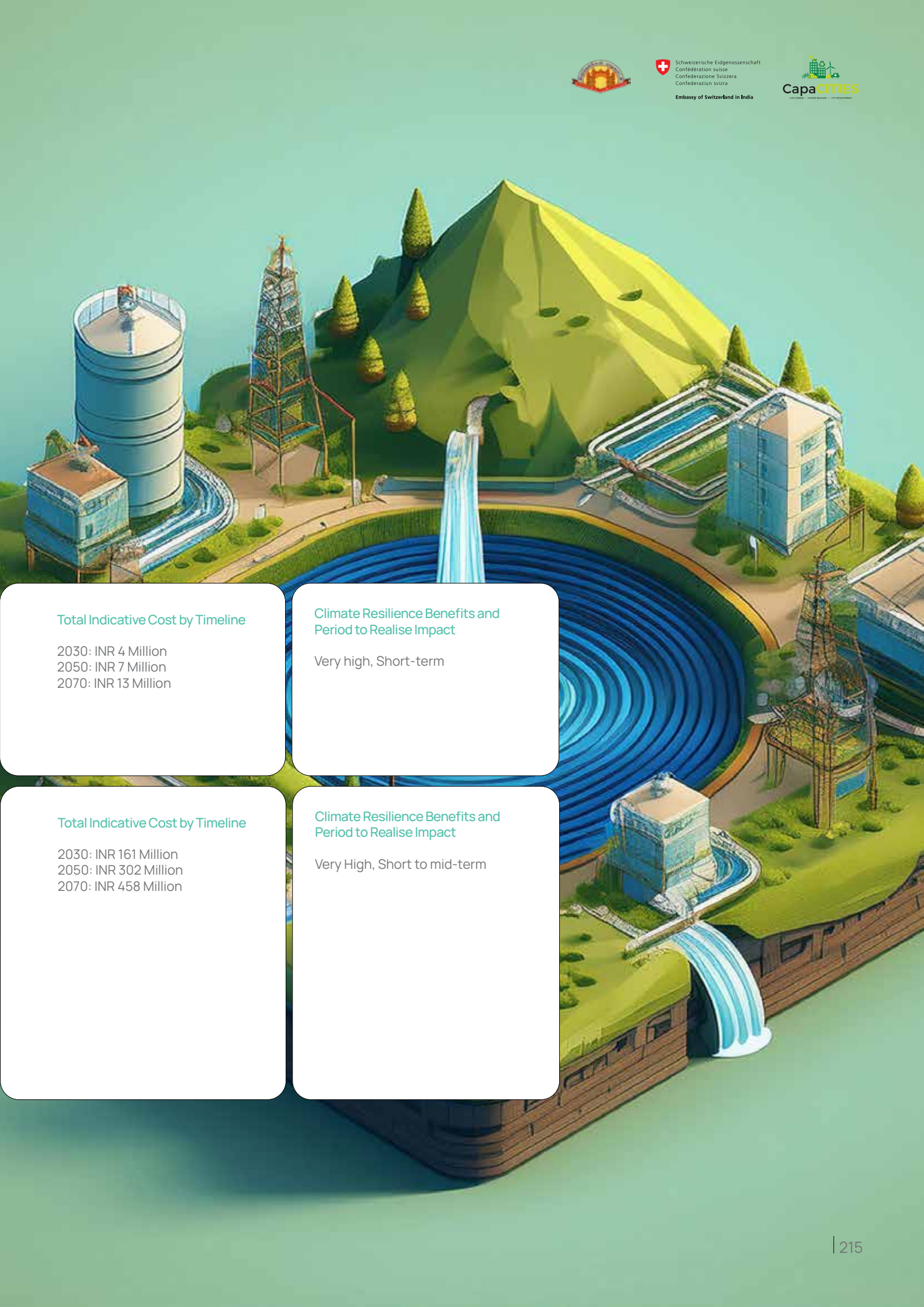
2030: 20% of total demand
2050: 40% of total demand
2070: 60% of total demand

Implementation Entities and Financing Mode

- Engineering Department, TCMC,
- TNGECL, TNERC, TANGEDCO
- Solar PV developers and service providers

Financing Mode:

- Municipal budget.
- RESCO model with private sector investment.
- Issuance of Green bonds.
- 15th Finance Commission



Total Indicative Cost by Timeline

2030: INR 4 Million
2050: INR 7 Million
2070: INR 13 Million

Climate Resilience Benefits and Period to Realise Impact

Very high, Short-term

Total Indicative Cost by Timeline

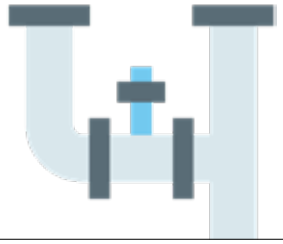
2030: INR 161 Million
2050: INR 302 Million
2070: INR 458 Million

Climate Resilience Benefits and Period to Realise Impact

Very High, Short to mid-term

Action 3

Reduce NRW and leakages to reduce energy usage in water networks.



Detailed Targets & Sub-actions

11% reduction in NRW levels by 2050

Implementation Entities and Financing Mode

- Engineering Department, TCMC

Financing Mode:

- TCMC municipal budget
- AMRUT 2.0,

Enabling Actions

Implement financing mechanisms such as Energy Performance Contracting for pump replacements, partnering with agencies like EESL.

Evaluate LT/HT load in water facilities to determine the potential for net metering and captive RE power plants.

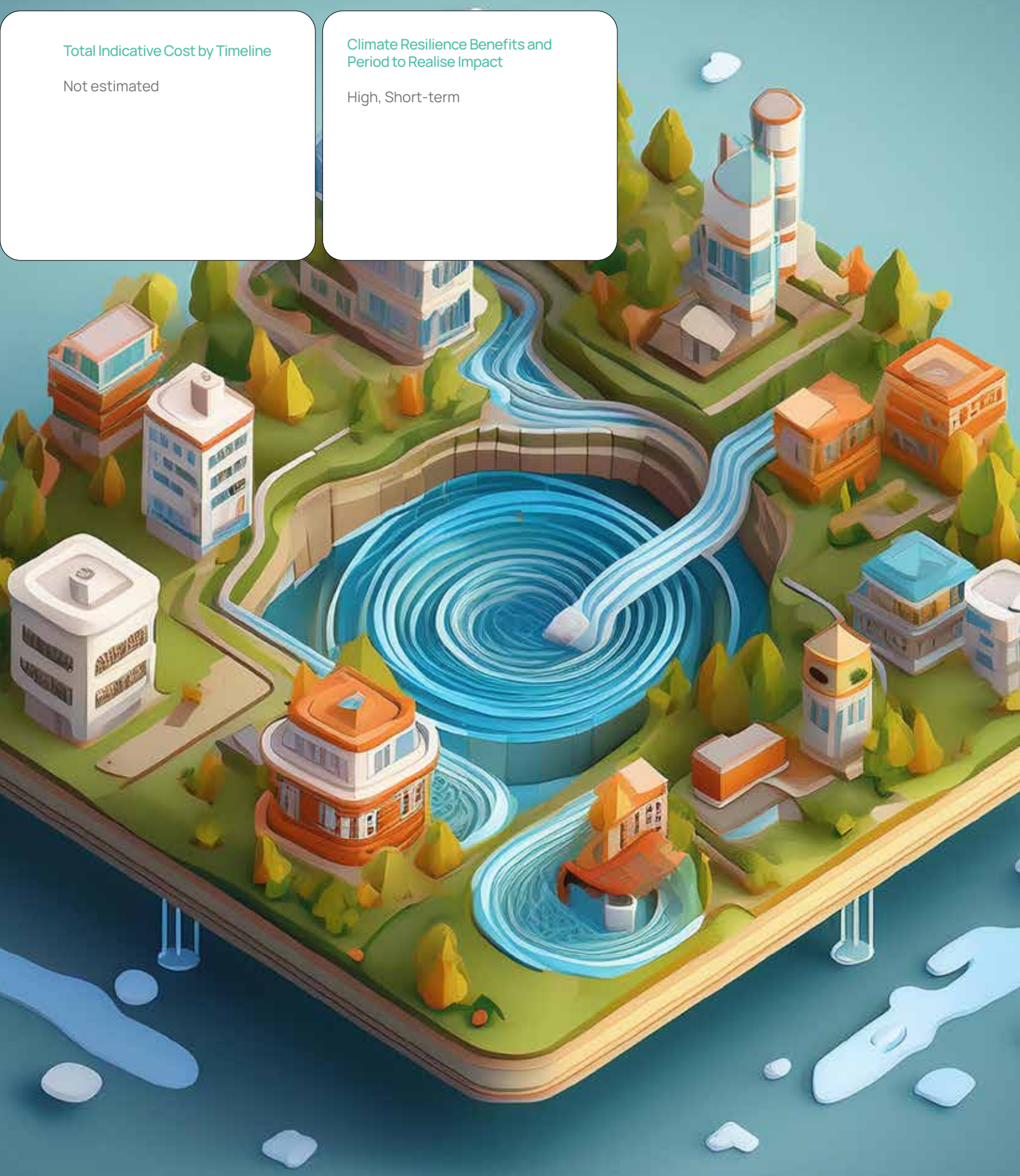
Analyse the benefits and feasibility of integrating battery energy storage systems with RE sources.
Collaborate with TANGEDCO to deploy RE power plants, aligning efforts with their RE targets.

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short-term



8.3.3.2 Adaptation Strategies for Water Supply

Goal

Augment water resilience of the city and reuse 100% treated wastewater to meet commercial and industrial water demand.

Strategy 1: Frame local policies and rules for water resource management and implement water conservation measures.

Action 1

Prepare local water resource management plan, including for ground water management, and identify alternative sources of supply for water resilience.

Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:
Increase water withdrawal from Ariyanayagipuram headworks as per water demand.

Regulate groundwater extraction and explore groundwater as alternative source during times of disaster and water scarcity.

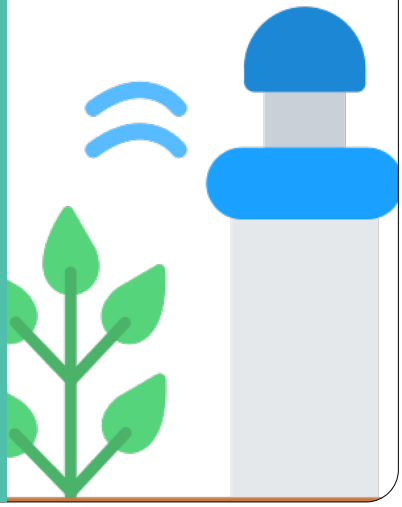
Detailed assessment of water supply capacity and rejuvenation of all lakes managed by TCMC

Potential Locations and Beneficiaries

- City-wide impact

Action 2

Promote rainwater harvesting (RWH) and implement groundwater recharge structures to enhance water resilience of Tirunelveli.



Existing Scenario/Proposed Initiatives and Actions

Existing Status: TCMC has installing shallow groundwater recharge structures across 25 locations in Palayamkottai and Melapalayam zones, which are mostly defunct.

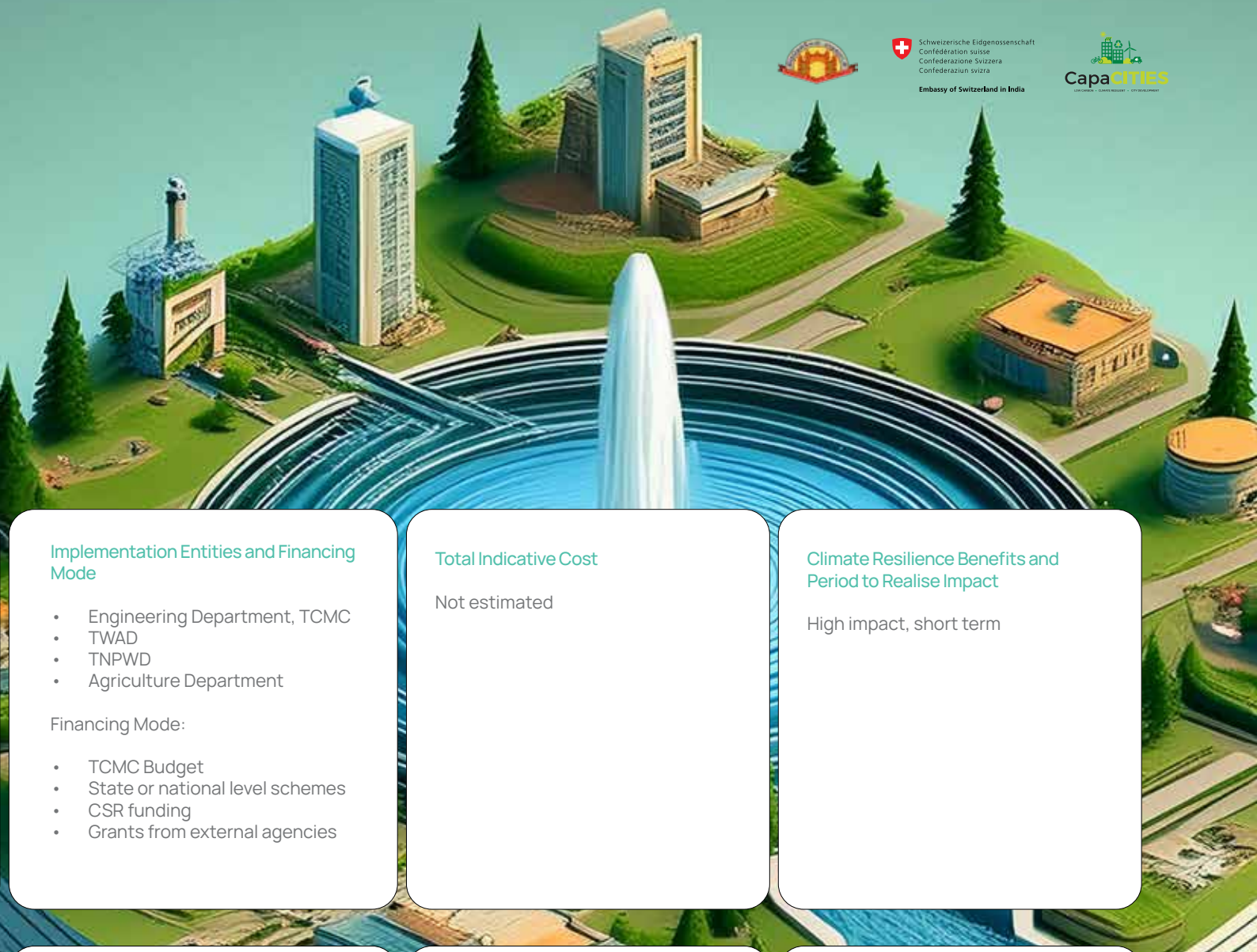
Proposed Actions:

- Awareness generation on benefits of RWH.
- Collaborate with private entities to implement public groundwater recharge structures under CSR/CER funding.
- TCMC will install groundwater recharge structures that have been identified as heat stressed based on the study. Public parks may be suitably modified to achieve better outcomes.

Potential Locations and Beneficiaries

Across city, especially in:

- Open grounds
- Playgrounds
- Low-lying areas
- Riverbanks
- Park sites and OSR land
- Under flyovers



Implementation Entities and Financing Mode

- Engineering Department, TCMC
- TWAD
- TNPWD
- Agriculture Department

Financing Mode:

- TCMC Budget
- State or national level schemes
- CSR funding
- Grants from external agencies

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, short term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- CSR Funds

Financing Mode:

- TCMC Budget
- State or national level schemes
- CSR funding
- Grants from external agencies

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short-term

Action 3

Conduct NRW study and monitoring of district metered water supply by SCADA system.

Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:

City-wide NRW study on old and new water supply infrastructure

City-wide implementation of district metered water supply management for early detection of water leakages

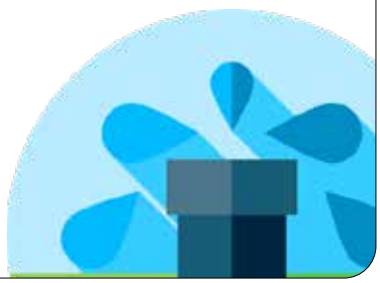
Develop a monitoring plan with SCADA system for early detection of water supply issues and rectification.

Potential Locations and Beneficiaries

- City areas with piped water supply network (including all locations from the headworks and downstream)

Action 4

Stringent monitoring of RWH structures implemented as per TNCDBR - 2019



Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: All new properties in the city are mandated to have RWH structures implemented as per TNCDBR 2019.

Proposed Actions:

Monitoring and periodic maintenance of RWH structures implemented by providing incentives based on building inspection report and random periodic checks

Potential Locations and Beneficiaries

Entire city

Strategy 2: City-wide coverage and 24X7 water supply through an efficient water distribution network with reduced NRW

Action 1

Augment existing water supply and treatment capacity to satisfy rising demand from new growth regions and improve water quality.

Existing Scenario/Proposed Initiatives and Actions

Proposed projects:

10 MLD Murappanadu water supply scheme to meet growing water demand in Palayamkottai zone

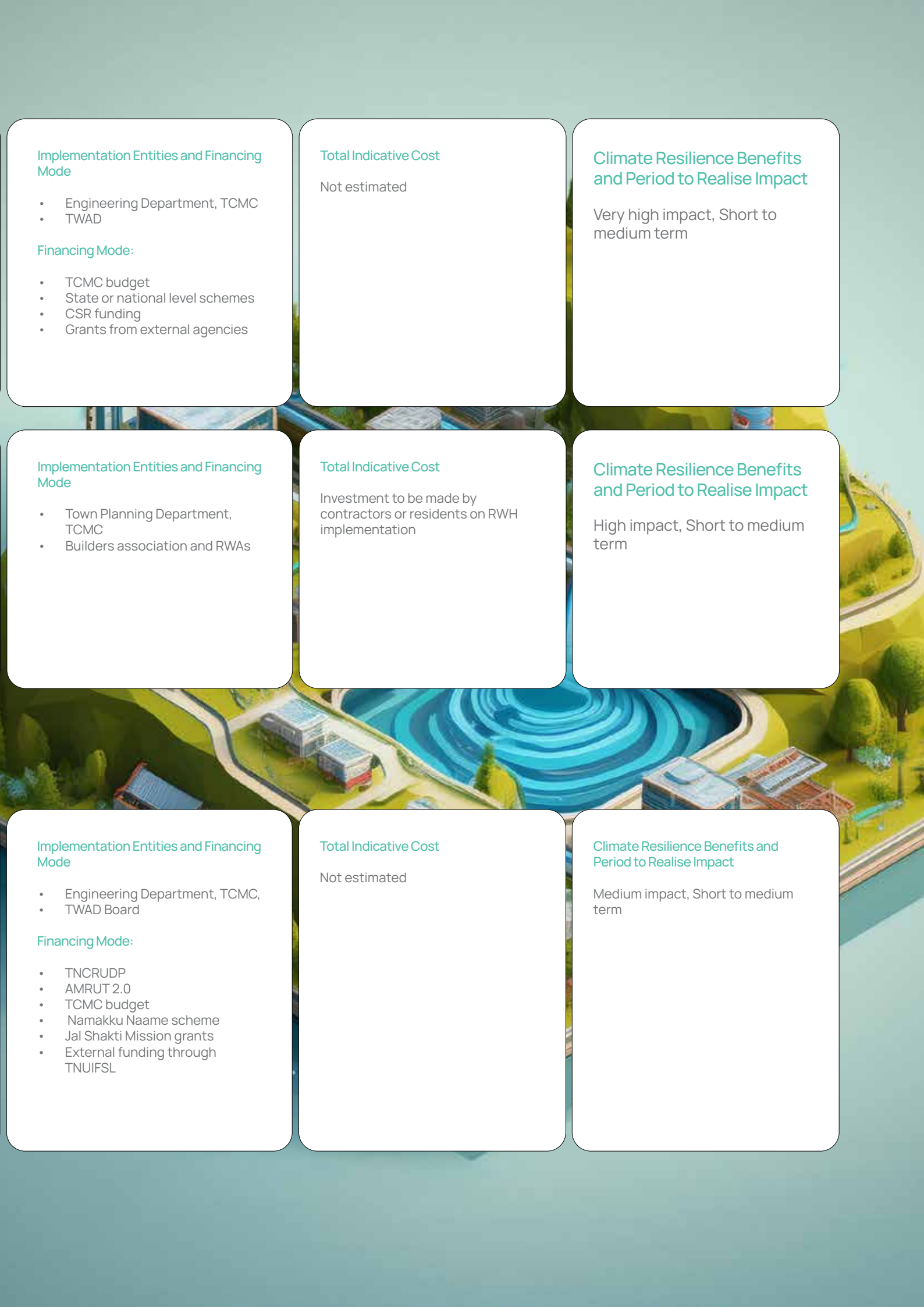
Proposed Actions:

Implement adequate WTPs to improve water quality of existing water supply network.

Rejuvenation of lakes including development of decentralised STPs to enables lakes to supplement main water supply resources when needed

Potential Locations and Beneficiaries

- Efficient water supply in developing areas, particularly in Palayamkottai zone and augment water treatment capacity to improve water quality.
- Potential Locations:
- Newly developing areas with high population growth such as wards 37, 38, 39, 53, 54 and 55



Implementation Entities and Financing Mode

- Engineering Department, TCMC
- TWAD

Financing Mode:

- TCMC budget
- State or national level schemes
- CSR funding
- Grants from external agencies

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Short to medium term

Implementation Entities and Financing Mode

- Town Planning Department, TCMC
- Builders association and RWAs

Total Indicative Cost

Investment to be made by contractors or residents on RWH implementation

Climate Resilience Benefits and Period to Realise Impact

High impact, Short to medium term

Implementation Entities and Financing Mode

- Engineering Department, TCMC,
- TWAD Board

Financing Mode:

- TNCRUDP
- AMRUT 2.0
- TCMC budget
- Namakku Naame scheme
- Jal Shakti Mission grants
- External funding through TNUIFSL

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Medium impact, Short to medium term

Action 2

24X7 water supply with district metered area-based water supply

Existing Scenario/Proposed Initiatives and Actions

Planned projects:

24X7 metered water supply in 4 pilot zones of city

Proposed actions:

City-wide implementation of 24X7 water supply at 135 lpcd with district metered water supply

Include areas not covered by water supply into the water supply network as part of this effort.

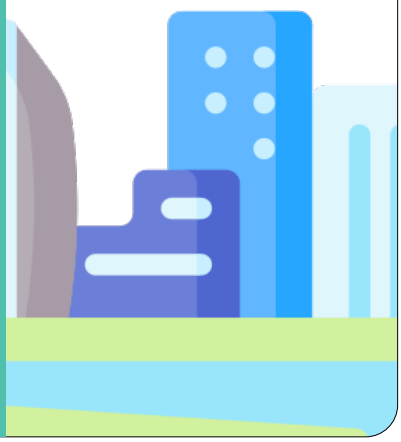
Potential Locations and Beneficiaries

- Potential for city-wide replication depending on success of pilot

Strategy 3: Undertake ecological restoration of lakes and Thamirabarani riverfront to enhance water resilience of city.

Action 1

Rejuvenation and ecological restoration of lakes and Thamirabarani river front



Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: Majority of the lakes in the city have sewage inflow and are not potable. No lake in the city is used as a water supply source. Pambankulam and Veinthankulam are being rejuvenated under AMRUT 2.0 scheme.
Proposed Actions:

Build decentralised STP or DEWATS at wastewater entry points to lakes and Thamirabarani River.

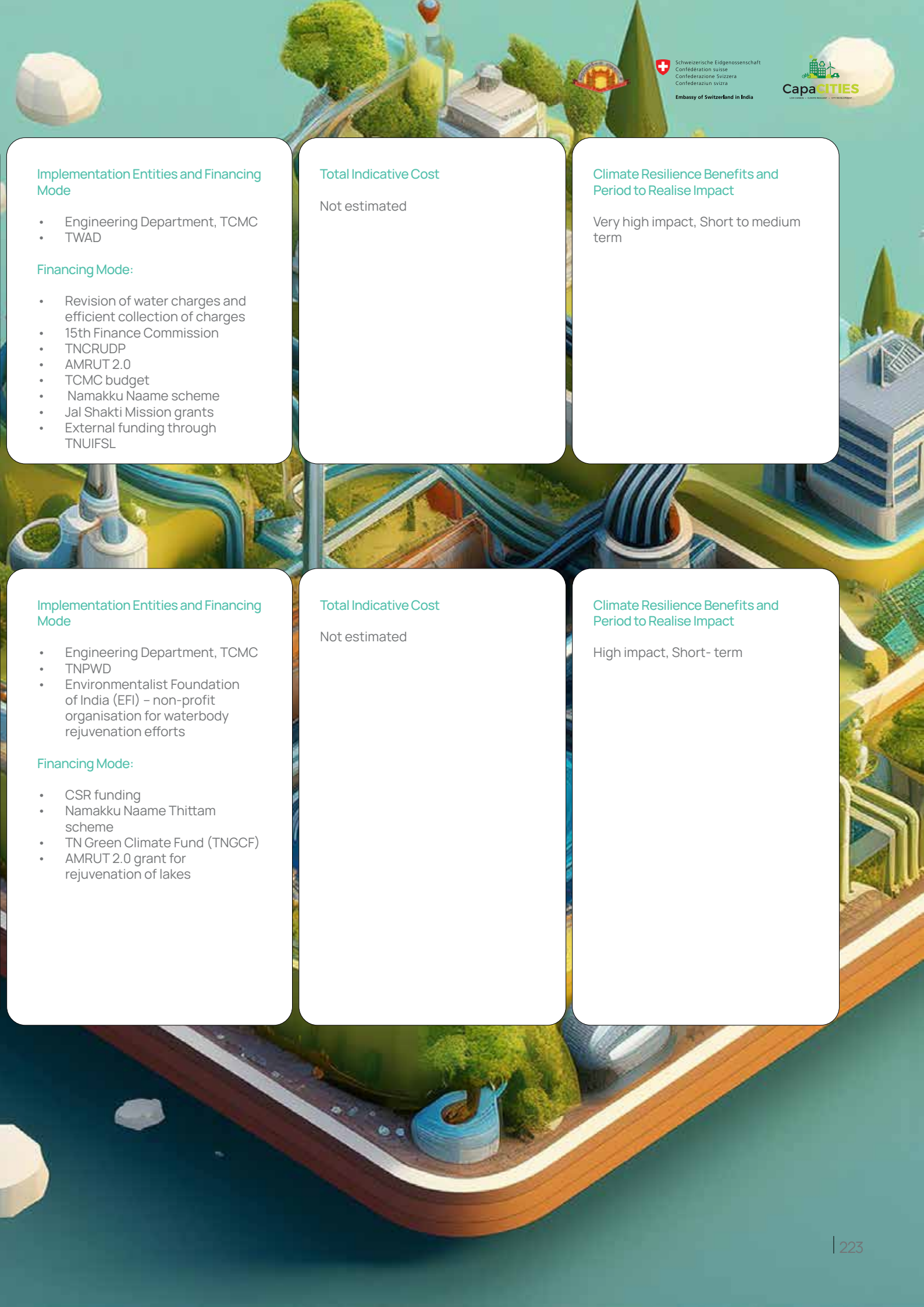
Desilting of all lakes in the city in collaboration with TNPWD and removing of encroachments.

Developing constructed/floating wetlands and bird islands to improve water quality

Implement aeration points in polluted lakes to improve natural rejuvenation capabilities of water bodies.

Potential Locations and Beneficiaries

- Potential Lakes: Udaiyarpatti, Nainarkulam, Kandiyaperi, Krishnaperi, Elanthakulam, Vettuvankulam
- Potential beneficiaries: Entire city



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Implementation Entities and Financing Mode

- Engineering Department, TCMC
- TWAD

Financing Mode:

- Revision of water charges and efficient collection of charges
- 15th Finance Commission
- TNCRUDP
- AMRUT 2.0
- TCMC budget
- Namakku Naame scheme
- Jal Shakti Mission grants
- External funding through TNUIFSL

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Short to medium term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- TNPWD
- Environmentalist Foundation of India (EFI) – non-profit organisation for waterbody rejuvenation efforts

Financing Mode:

- CSR funding
- Namakku Naame Thittam scheme
- TN Green Climate Fund (TNGCF)
- AMRUT 2.0 grant for rejuvenation of lakes

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short- term

8.3.4 Wastewater

2021

Baseline status Wastewater

GHG emissions:
1,561 tCO2e (8.52% of total municipal GHG emissions)

Key statistics:
18.58% of total households are covered by underground sewerage networks.

Tirunelveli's total domestic wastewater generation was about 54.86 MLD.

The city's existing sewerage infrastructure encompasses a network of 187.27 km of sewer lines and 12.55 km of sewer mains, complemented by 4 pumping stations scattered throughout the city.

Opportunities and challenges/gaps

Frequent break down and leakages due to old sewerage network and overflow of sewerage network due to illegal drainage connections

Inefficient sewerage network design and underutilised STPs with low methane recovery

Potential users of recycled wastewater are using groundwater due to limited control over groundwater extraction.

Ineffective implementation of faecal sludge and septage management action plan

There is an opportunity to opt for anaerobic treatment systems in new STPs, capture methane gas from wastewater and use it for energy generation. There is a possibility to retrofit existing STPs with secondary treatment technology to improve the current standards of the water quality to a non-hazardous level mandated by WHO after treatment.

Existing policy and ongoing initiatives

Phase II and Phase III of UGSS scheme under implementation

58 MLD SBR technology based STP to be implemented under AMRUT 2.0 at Ramayanpatti

Climate Risk and BAU GHG Emissions Scenario

Residential Buildings	BAU GHG Emissions (Million tCO2e)			Share in overall BAU GHG Emissions (%)		
	2030	2050	2070	2030	2050	2070
Wastewater	0.01	0.02	0.02	0.92%	1.07%	0.92%

Note: Projected emissions include those from electricity consumption in municipal wastewater services, as well as emissions from domestic wastewater management and treatment.

Climate Risk Status: High I High risk during intense rainfall

Extreme rainfall events cause stormwater to mix with sewerage lines, thus overwhelming the system and causing backflow due to pressure and diluting the inlet to STP causing disruptions in STP operations.

Openly dumped solid waste entering the sewerage system due to various openings causes blockages and compromises the smooth flow of wastewater to STP. This often causes leakages from man-holes of sewer lines which then mix with stormwater or water supply network.

Potential climate resilience impact from identified interventions (Net-zero scenario)

GHG Mitigation Potential and Indicative Cost of Interventions

Particulars	Net-zero Scenario Net-zero Scenario		
	2030	2050	2070
GHG emissions reduction from BAU (%)	20%	38%	40%
Total cost of mitigation actions (Million INR)	NA		
Total cost of adaptation actions (Million INR)	INR 390 million		

Climate Resilience Impact

Prevents contamination of stormwater and groundwater, and related health impacts

Enhanced sanitation standards in the city; lowers impacts from urban flooding risks

Improved operational efficiency and cost-effectiveness of wastewater management

Conservation of water through reuse of treated wastewater for non-drinking purposes

Lower methane emissions from anaerobic treatment plants and recovery of methane for energy production

SDGs

8.3.4.2 Mitigation Strategies for Wastewater Sector

Goal

Encourage development of zero-emission transport infrastructure and adoption of clean mobility options.

Target

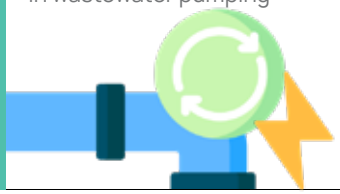
90% adoption of energy-efficient equipment for wastewater infrastructure and **60%** of energy demand to be met by RE sources

100% new plants use anaerobic treatment with methane gas capture and reuse

Strategy 1: Enhance operational and energy performance of wastewater infrastructure using energy efficient equipment and low-emission processes

Action 1

Promote adoption of energy efficient equipment in wastewater pumping

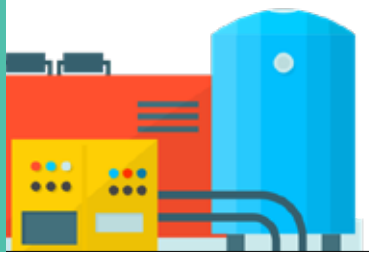


Detailed Targets & Sub-actions

2030: 40% of existing pumps
2050: 60% of existing pumps
2070: 90% of existing pumps

Action 2

Deploy solar PV plants with net metering in wastewater treatment facilities, including pumping stations and STP.



Detailed Targets & Sub-actions

Estimated capacity/size:
Solar:

2030: 20% of demand
2050: 40% of demand
2070: 60% of demand

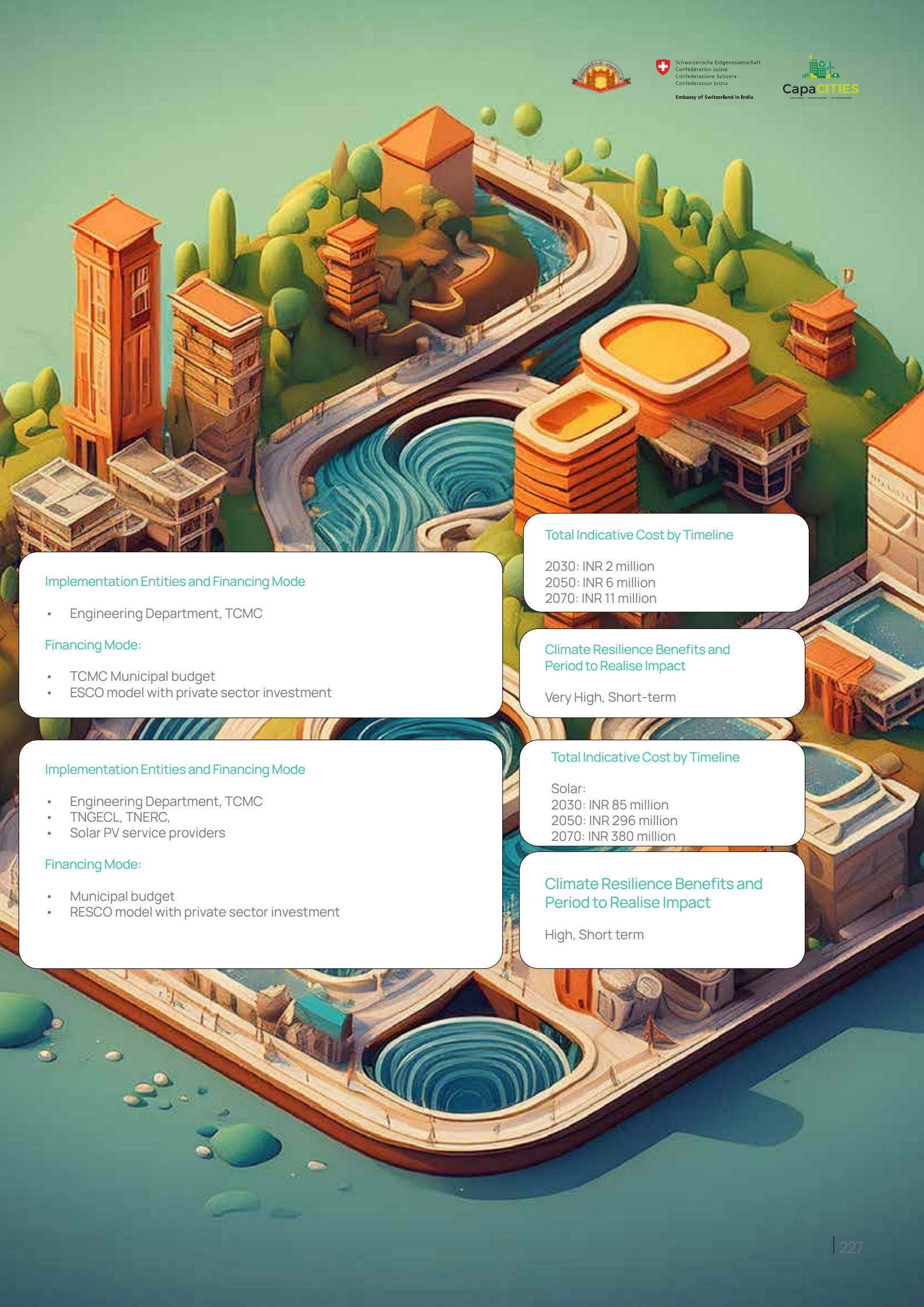
Enabling Actions

Implement financing mechanisms like Energy Performance Contracting, facilitated by agencies like EESL, to fund pump replacements.

Conduct an assessment of LT/HT load in wastewater treatment to determine the potential scale of net metering and captive RE power plants.

Request TNERC to extend RE power banking duration to one year instead of monthly cycles, potentially enhancing financial viability for RE initiatives.
Evaluate the advantages and scalability of battery energy storage deployment in conjunction with RE sources.

Investigate opportunities for collaboration with TANGEDCO/ TNGECL to deploy RE power plants, aligning with their RE objectives and fostering mutual benefits.



Implementation Entities and Financing Mode

- Engineering Department, TCMC

Financing Mode:

- TCMC Municipal budget
- ESCO model with private sector investment

Total Indicative Cost by Timeline

2030: INR 2 million
2050: INR 6 million
2070: INR 11 million

Climate Resilience Benefits and Period to Realise Impact

Very High, Short-term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- TNGECL, TNERC,
- Solar PV service providers

Financing Mode:

- Municipal budget
- RESCO model with private sector investment

Total Indicative Cost by Timeline

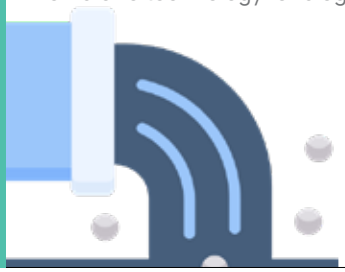
Solar:
2030: INR 85 million
2050: INR 296 million
2070: INR 380 million

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Action 1

All new wastewater treatment plants to use anaerobic treatment systems with dual membrane technology for biogas capture



Detailed Targets

Existing Scenario: 58 MLD SBR technology based STP proposed at Ramayanpatti under AMRUT 2.0; It does not have methane recovery system.

Proposed Actions:

Include biogas capture in scope of 58 MLD STP or deploy separate methane recovery system.
New wastewater treatment plants to be implemented in the future to use anaerobic system with biogas capture technology

Action 2

Improve the efficiency of treatment and operational performance of aerobic treatment facilities.

Detailed Targets

Extent of aerobic treatment capacity targeted for improvements:

2030: 100% of aerobic capacity
2050: 100% of aerobic capacity
2070: 100% of aerobic capacity

Proposed Actions:

Implement aeration systems or biological treatment methods to improve operational performance of existing STP.

Enabling Actions

TCMC can implement automation in wastewater treatment plants to ensure they operate at peak efficiency, reducing manual intervention and improving reliability.

Standard operating procedures will be developed and regular monitoring of sewage flows using catchment analyses and real-time data will help optimise the intake of treatment plants and ensuring consistent performance.

TCMC can conduct regular assessments of treatment plant efficiencies to identify opportunities for operational improvements and optimise pumping systems.

Encouraging the adoption of anaerobic or decentralised systems, using the generated gas or electricity to further enhance sustainability and reduce reliance on non-RE sources

Implementation Entities and Financing Mode

- Engineering Department, TCMC; technology providers

Financing Mode:

- Municipal budget
- PPP with private sector investment and sale of biogas to industries for replacing other lesser clean fuel types
- AMRUT 2.0

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high, Mid-term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- STP technology providers

Financing Mode:

- TCMC Municipal budget
- AMRUT 2.0

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high, Short-term

8.3.4.1 Adaptation Strategies for Wastewater Sector

Goal

Reuse 100% of treated wastewater to meet commercial and industrial water demand.

Strategy 1: City-wide coverage of sewerage network and wastewater treatment facilities; reuse of 100% of treated wastewater

Action 1

100% sewerage network coverage and wastewater treatment up to reuse standards

Existing Scenario/Proposed Initiatives and Actions

Current Status: 18.88% of UGSS coverage in the city, lack of adequate treatment capacity.
Phase II and Phase III of UGSS scheme under implementation and new 58.MLD STP proposed.

Proposed Actions:

Implementation of tertiary treatment plant at Ramayanpatti for wastewater reuse

Development of dedicated network to enable offtake of tertiary treated wastewater from Ramayanpatti STP site.

Potential Locations and Beneficiaries

Potential Areas for Implementation:

- City-wide implementation.
- Wastewater tertiary treatment infrastructure at Ramyanpatti and connecting network to locations in proximity that can use treated wastewater such as the Gangaikondan SEZ 20 km away from city, and in areas where larger industries and institutions are located

Action 2

Prepare policy on reuse of treated wastewater for agriculture, industrial and commercial purposes.

Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: No tertiary treatment and wastewater use existing in city

Ground water is currently used by industries and the commercial sector including supply by water tankers.

Proposed Actions:

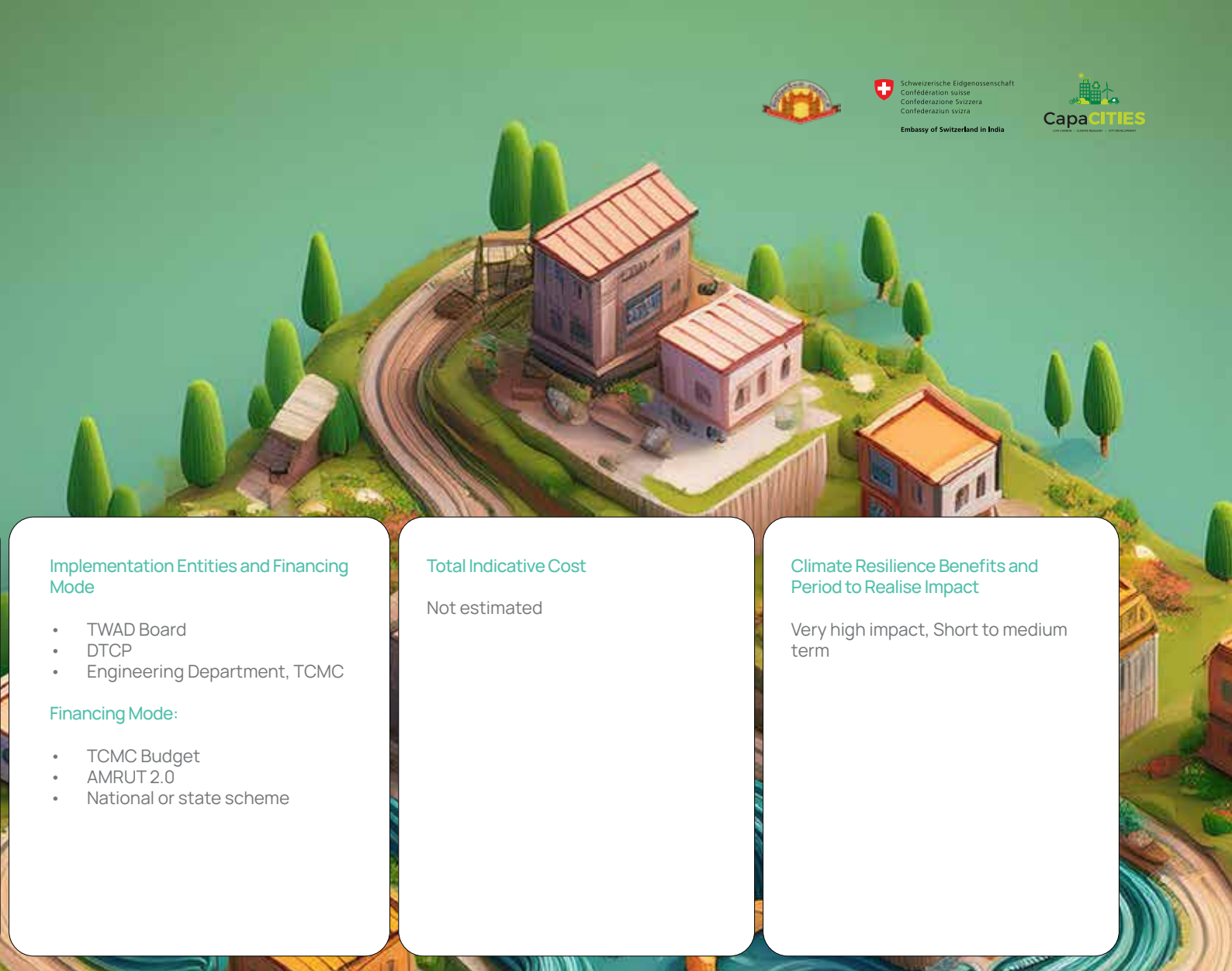
Identify challenges and opportuntiies in tertiary treatment of wastewater and its reuse.

Collaborate with relevant agencies such as TNPCB, TIDCO to mandate wastewater reuse by large commercial and industrial entities.

Potential Locations and Beneficiaries

Potential Areas for Implementation:

- Gangaikondan Industrial SEZ and IT Park
- MSME industries and commercial establishments in Thachanallur and Tirunelveli zones, especially on the northern and western fringes of the city



Implementation Entities and Financing Mode

- TWAD Board
- DTCP
- Engineering Department, TCMC

Financing Mode:

- TCMC Budget
- AMRUT 2.0
- National or state scheme

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Short to medium term

Implementation Entities and Financing Mode

- TCMC
- TWAD Board
- TNPCB, Industries Department
- Municipal Administration and Water Supply (MAWS) Department, Public Works Department of GoTN

Financing Mode:

- TCMC Budget
- AMRUT 2.0
- National or state scheme
- National or state scheme

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Medium impact, Short to medium term

Action 3

Replacing defunct sewerage network implemented in 1989 and damaged UGSS pipes under Phase I UGSS

Existing Scenario/Proposed Initiatives and Actions

Frequent issues of UGSS pipe leakage and overflow from manholes witnessed in many wards and implementation of Phase II and Phase III UGSS scheme on-going

Proposed Actions:

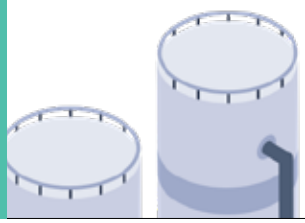
Replacement of defunct sewerage lines in Tirunelveli town and junction areas, with new pipes and manholes revamped where necessary

Potential Locations and Beneficiaries

- Potential Wards for Implementation: 3, 12, 28, 29, 30, 40, 53, 55
- Potential Beneficiaries: Citizens living in the wards with vulnerable UGSS network

Action 4

Promote decentralised wastewater treatment and dual plumbing system as indicated in in TNDBCR for projects with 2,500 sq m built up area or more.



Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:

Mandate dual plumbing and decentralised STP in multi-storey residential and commercial buildings to improve water efficiency and reduce wastewater generation.

- Mandate all large public buildings and social housing projects.
- Encourage existing large buildings to retrofit dual plumbing to reduce wastewater generation.

Potential Locations and Beneficiaries

- Potential Locations:
- TNHUDB housing developments, new apartments coming up in developing areas in the eastern part of city
- Potential Beneficiaries: City scale implementation

Strategy 1: City-wide coverage of sewerage network and wastewater treatment facilities; reuse of 100% of treated wastewater

Action 1

Develop faecal sludge management action plan and implement measures to minimise faecal sludge reaching water bodies.

Existing Scenario/Proposed Initiatives and Actions

Current Status: Sewage of around 37% households in the city area is managed via septic tanks. Faecal sludge is being collected periodically by private contractors and dumped in river or lakes in the city.

Proposed Actions:

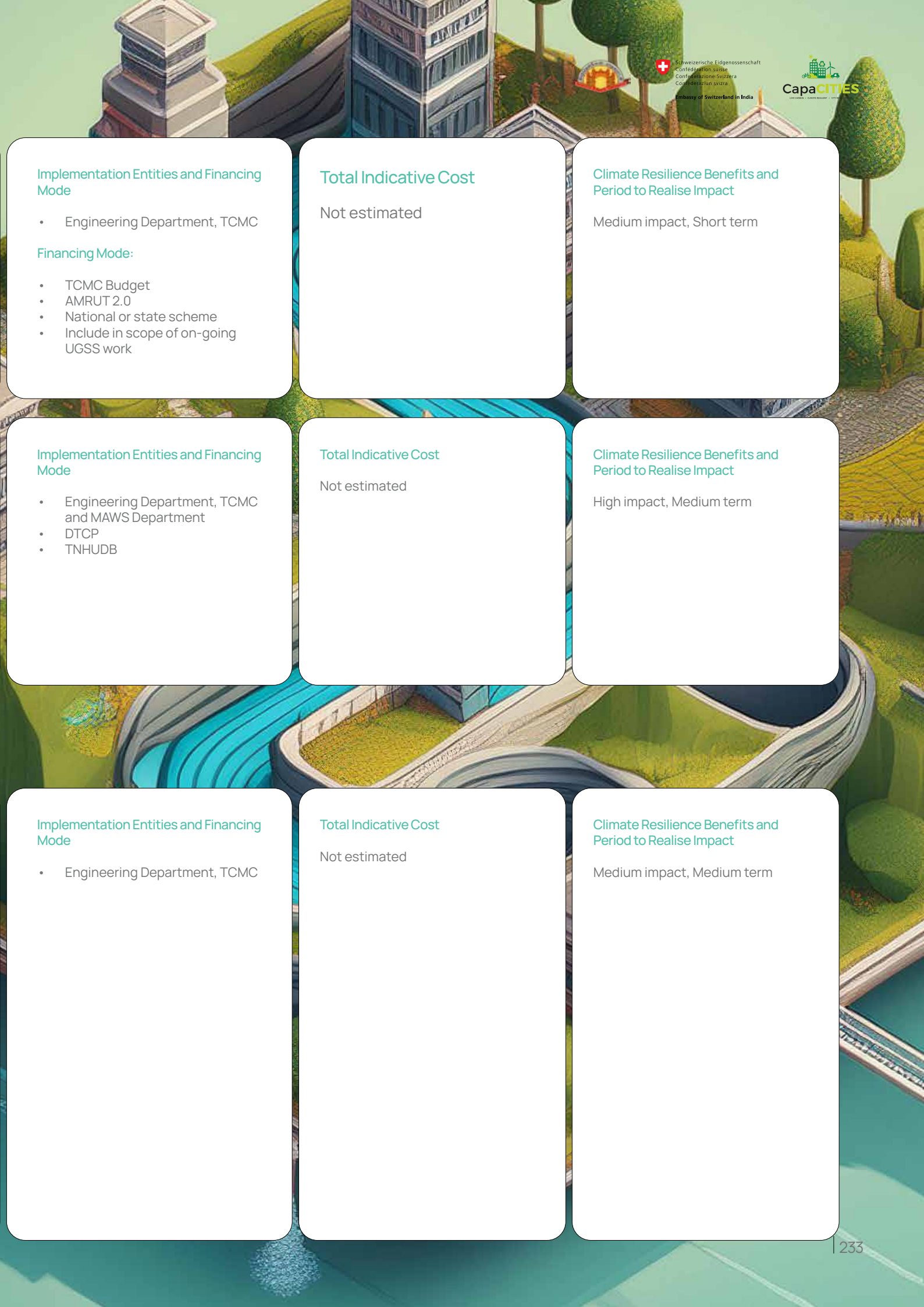
Regulate septic tank cleaning contractors.

Develop necessary infrastructure for treatment of faecal sludge at STP.

Monitor and record quantity of faecal sludge taken to STP.

Potential Locations and Beneficiaries

City-wide benefits



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Implementation Entities and Financing Mode

- Engineering Department, TCMC

Financing Mode:

- TCMC Budget
- AMRUT 2.0
- National or state scheme
- Include in scope of on-going UGSS work

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Medium impact, Short term

Implementation Entities and Financing Mode

- Engineering Department, TCMC and MAWS Department
- DTCP
- TNHUDB

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Medium term

Implementation Entities and Financing Mode

- Engineering Department, TCMC

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Medium impact, Medium term

Action 2

Develop decanting stations at STP site for treatment of sludge from septic tanks.

Existing Scenario/Proposed Initiatives and Actions

Proposed Action: Build decanting wells near Ramayanpatti STP to enable preliminary treatment of faecal sludge from septic tanks and pumping into STP.

Potential Locations and Beneficiaries

City-wide benefits

Implementation Entities and Financing Mode

- Engineering Department, TCMC

Total Indicative Cost

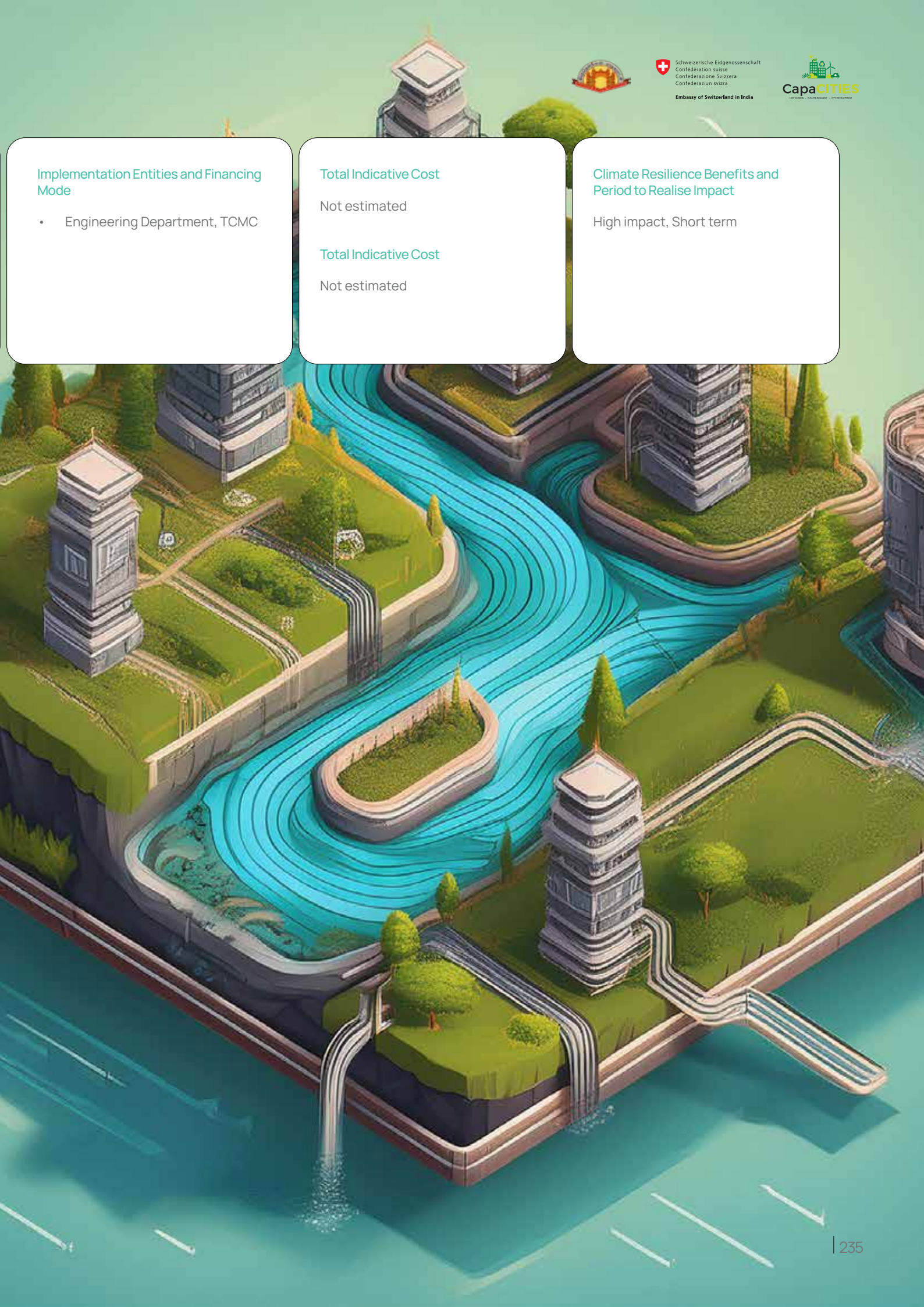
Not estimated

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short term



8.3.5 Stormwater

2021

Baseline status
Stormwater

Key statistics:
Inadequate stormwater drainage network, and existing lined and unlined stormwater drains lack capacity to convey large quantities of stormwater during extreme rainfall events.

Opportunities and challenges/gaps

Open waste dumping in drains leads to siltation and clogging in the drains.

Encroachments impact flow of water in unlined (kuccha) drains that are very common in the city.

Existing policy and ongoing initiatives

Augmentation of stormwater drainage network with lined drains (pucca) in wards not covered by stormwater drains..

TCMC municipal budget allocation of INR 100 million in 2023-24 to build drains in the city

New stormwater drains and revamping of old drains in Tirunelveli zone under Capital Grant Fund from state government

Climate Risk Status: High I High risk during high intensity rainfall

High intensity rainfall causes waterlogging issues, especially in low lying areas, and can lead to health hazards like water and vector borne diseases.

Potential climate resilience impact from identified interventions (Net-zero scenario)

Total cost of adaptation actions (Million INR)

Not estimated

Climate Resilience Impact

Preventing water stagnation through well designed SWDs reduce impact of extreme rainfall events.

Periodic maintenance of natural drains and tanks and cascading of tanks will reduce impact of urban and riverine flooding.

Increased capacity of tanks and lakes will increase their effectiveness in acting as flood buffers and increase groundwater table in the city.

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8.3.5.1 Adaptation Strategies for Stormwater Sector

Goal

Increase resilience to urban flooding and riverine flooding during extreme rainfall events.

Strategy 1: Watershed management of natural drains in the city through sustainable urban planning practices to prevent urban flooding

Action 1

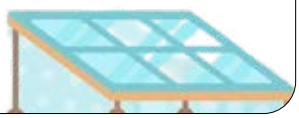
Develop and implement a GIS based watershed management plan.

Sub-actions:

Integrate watershed considerations into project planning stage.

Identify augmentation strategies for local water resources to increase resilience.

Protect and improve



Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: Most of the flood vulnerable points in Tirunelveli are due to lack of consideration of natural contours during the planning phase, inadequate SWD coverage and encroachments.

Proposed Actions:

SOP for roads and infrastructure development to consider natural contours based on watershed assessment and topological surveys

Remove encroachment in watershed areas and inlet and outlet drains of lakes which are obstructing flow of stormwater in the city.

Potential Locations and Beneficiaries

Potential locations:

- In areas where new planning permission or approvals for project development is requested
- Potential beneficiaries: City-wide benefit; People living along the banks of these natural drains will receive direct benefits.

Strategy 2: Rejuvenation of lakes to enable them to act as flood buffers and natural groundwater recharge areas

Action 1

Periodic de-siltation and removal of water hyacinth in existing water bodies

Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: All waterbodies in the city have the invasive species water hyacinth present, and absence of de-siltation efforts have reduced their water storage capacity.

Proposed actions:

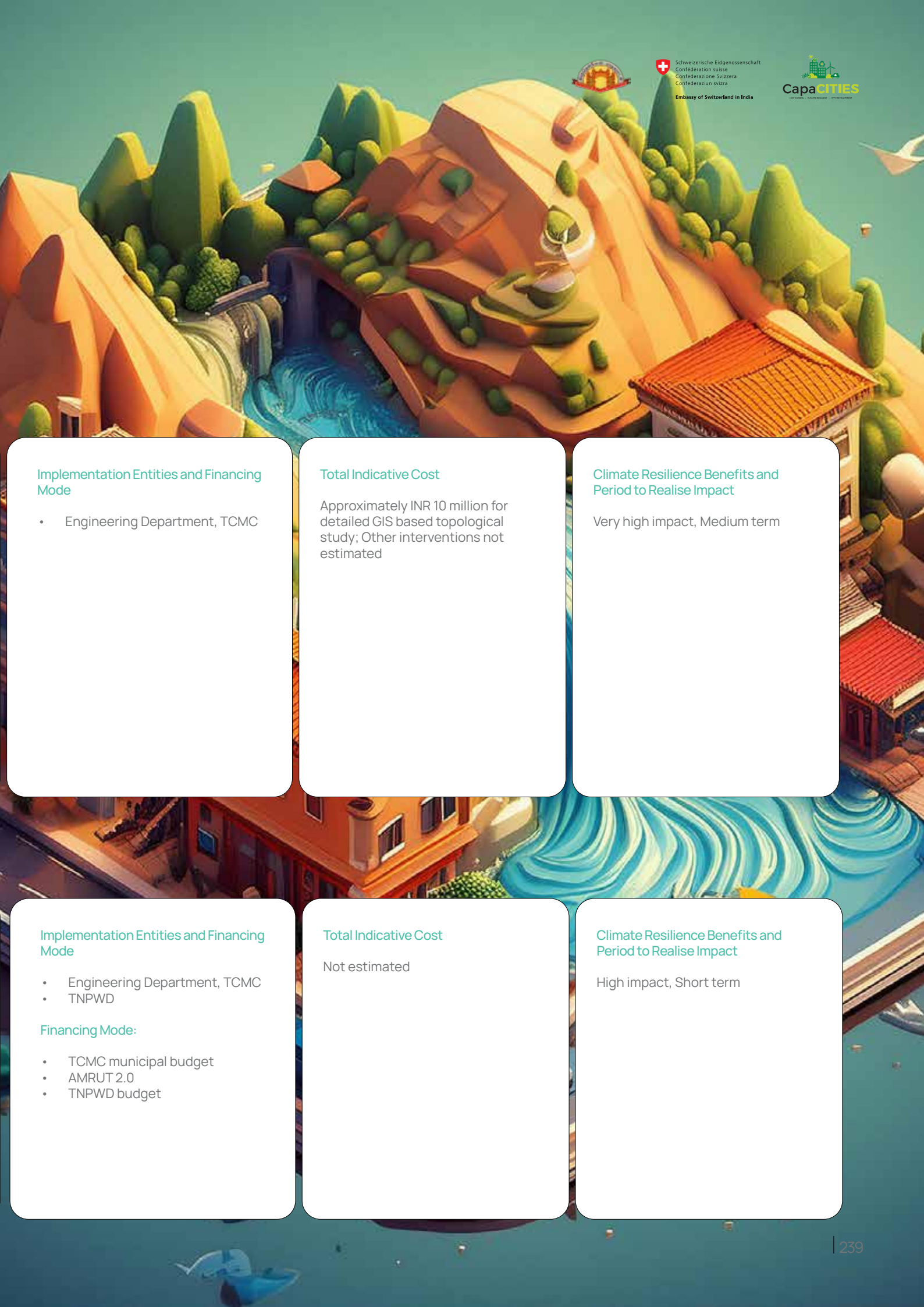
De-silt all water bodies to increase average depth of lakes by 20% to enhance capacity of the 27 lakes in the city.

Undertake periodic de-siltation efforts, at least once in 3 years, and remove water hyacinth every year.

Potential Locations and Beneficiaries

Potential Locations: 12 lakes managed by TCMC; 15 lakes managed by TNPWD

Potential Beneficiaries:
City-wide benefits through flood mitigation and increased water resilience



Implementation Entities and Financing Mode

- Engineering Department, TCMC

Total Indicative Cost

Approximately INR 10 million for detailed GIS based topological study; Other interventions not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Medium term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- TNPWD

Financing Mode:

- TCMC municipal budget
- AMRUT 2.0
- TNPWD budget

Total Indicative Cost

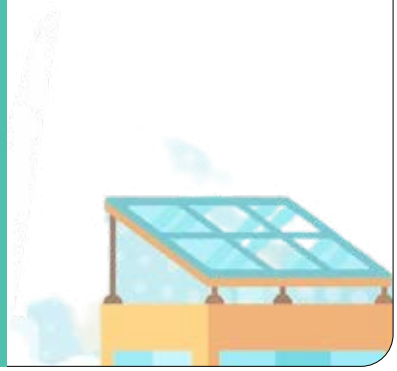
Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short term

Action 2

Remove encroachments on waterbodies and undertake suitable rejuvenation efforts.



Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: Several tanks in the city have encroachments on them or their water pathways, disrupting the natural flow of stormwater, leading to urban flooding risks.

Proposed actions:

Remove encroachments from tanks and their inlet or outlet drains that are disrupting the inflow and outflow of stormwater from watershed areas.

Undertake de-siltation to increase depth by at least 20% to increase water storage capacity.

Strengthen the bunds clearly marking boundaries of the tanks.

Potential Locations and Beneficiaries

Potential Locations:

Rajagopalapuram Lake, Elanthakulam, Vettuvankulam, Nochikulam

Potential Beneficiaries:

City-wide benefits through flood mitigation and increased water resilience.

Action 3

Develop connecting stormwater drains to enable cascading of tanks, especially in urban heat impacted Palayamakottai and Melapalayam zones.

Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: Large tanks in Tirunelveli and Thachanallur zones are connected through Kodagan and Tirunelveli canals but require periodic de-siltation and removal of water hyacinth.

Periyakulam and Veinthankulam in Melapalayam zone are already connected but the connecting drain is partially damaged.

Proposed actions:

Check feasibility through topological assessments and build connecting drains between lakes,

Revamp the existing drains in the watershed areas especially connecting inlet and outlet drains.

Revamp the outlet drains from lakes leading to the major irrigation canals or Thamirabarani River.
water storage capacity.

Strengthen the bunds clearly marking boundaries of the tanks.

Potential Locations and Beneficiaries

Potential Locations:

Anaiyarkulam, Watcherkulam, Periyakulam and Veinthankulam in Melapalayam zone.

Rajagopalapuram Lake, Nochikulam, Sivanadiyarkulam, and VM Chathram Lake in Palayamkottai zone.

Potential Pilot Projects:

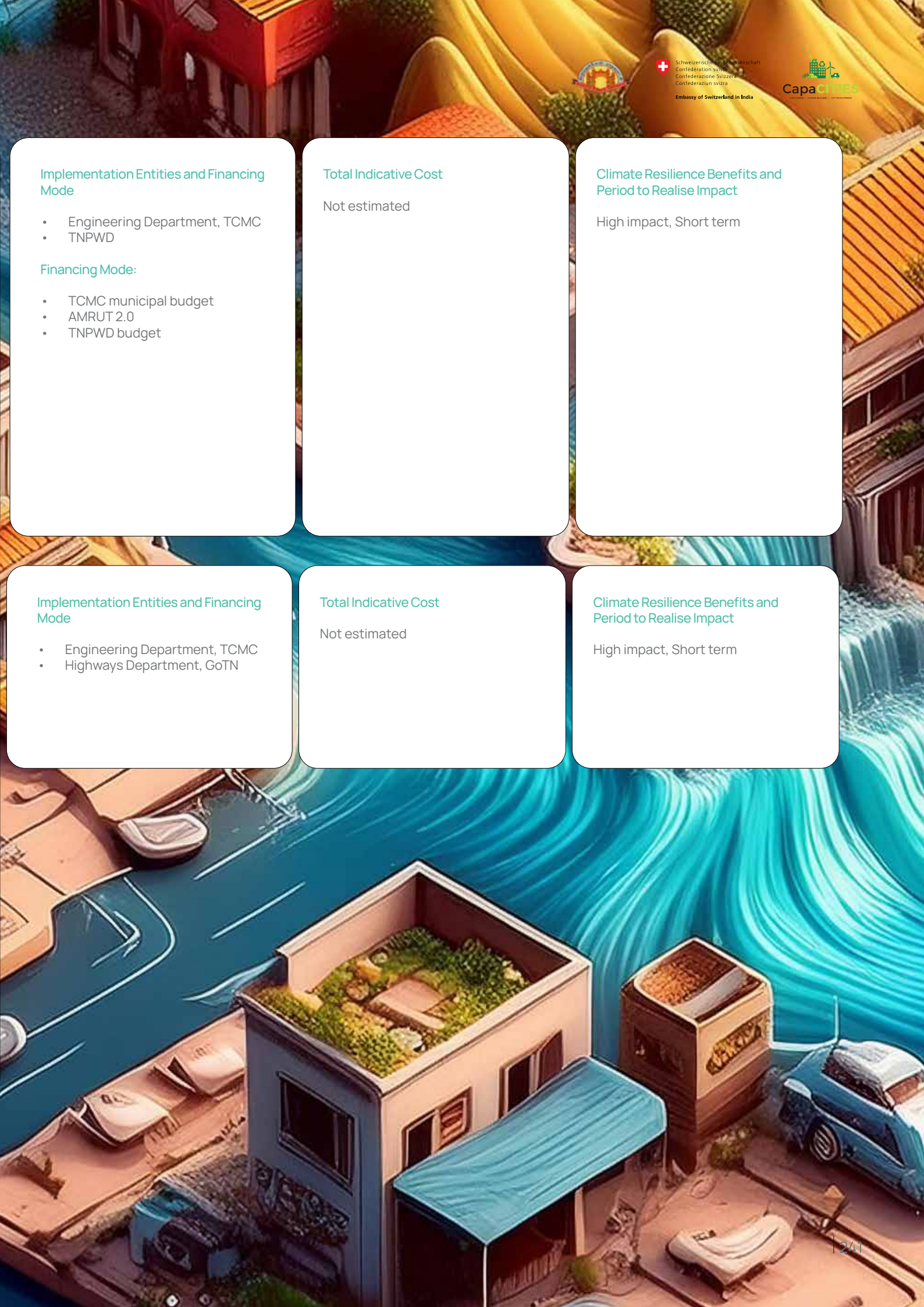
Connect Anaiyarkulam, Watcherkulam, Periyakulam.

Revamp the drain connecting Periyakulam and Veinthankulam.

Revamp the Veinthankulam outlet leading to Palayam canal.

Potential Beneficiaries:

Urban heat vulnerable wards: 40, 41, 42, 49, 53, 54, 55



Implementation Entities and Financing Mode

- Engineering Department, TCMC
- TNPWD

Financing Mode:

- TCMC municipal budget
- AMRUT 2.0
- TNPWD budget

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- Highways Department, GoTN

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short term

Strategy 3: City-wide coverage of stormwater drainage network and implementation of nature-based solutions for stormwater management

Action 1

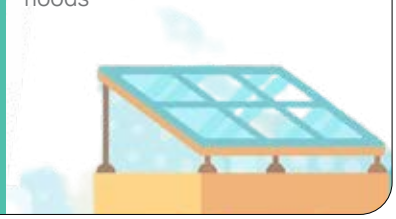
Improve the coverage of storm water drainage networks in areas prone to urban flooding.

Sub-actions:

Augment storm water drainage network and pumping stations.

Construct and maintain culverts and outfalls.

Deployment of flood sensors and developing an early warning system for urban floods



Existing Scenario/Proposed Initiatives and Actions

Current Status:

Storm water coverage in the city covers only around 26% of road and street network.

Urban flooding is also observed in the area where stormwater drainage network is not available or defunct.

Proposed Projects:

Increase storm water network coverage across, especially in flood vulnerable wards.

Rebuild defunct storm water drains and develop lined stormwater drains in locations with existing unlined stormwater drains.

Potential Locations and Beneficiaries

Potential locations:

Areas near the banks of river and canals running through the city

Developing areas with no SWD network and old town areas with defunct or poorly functioning SWD network

Areas located close to inlet and outlet drains of lakes

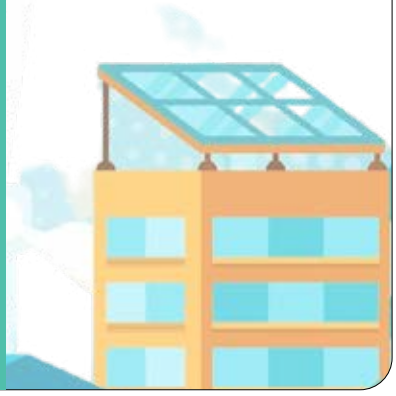
119 flood vulnerable locations identified

Potential Beneficiaries:

City-wide implementation and benefits

Action 2

Capture surface runoff through groundwater recharge measures in dedicated locations.



Existing Scenario/Proposed Initiatives and Actions

Current Status:

Groundwater recharge pits implemented in Palayamkottai and Melapalayam zones are defunct.

Proposed Actions:

Build groundwater recharge pits or bio-remediation pits to capture surface run-off.

De-silt or remove encroachments in old unlined stormwater drains along roads and develop natural swales to carry stormwater.

Potential Locations and Beneficiaries

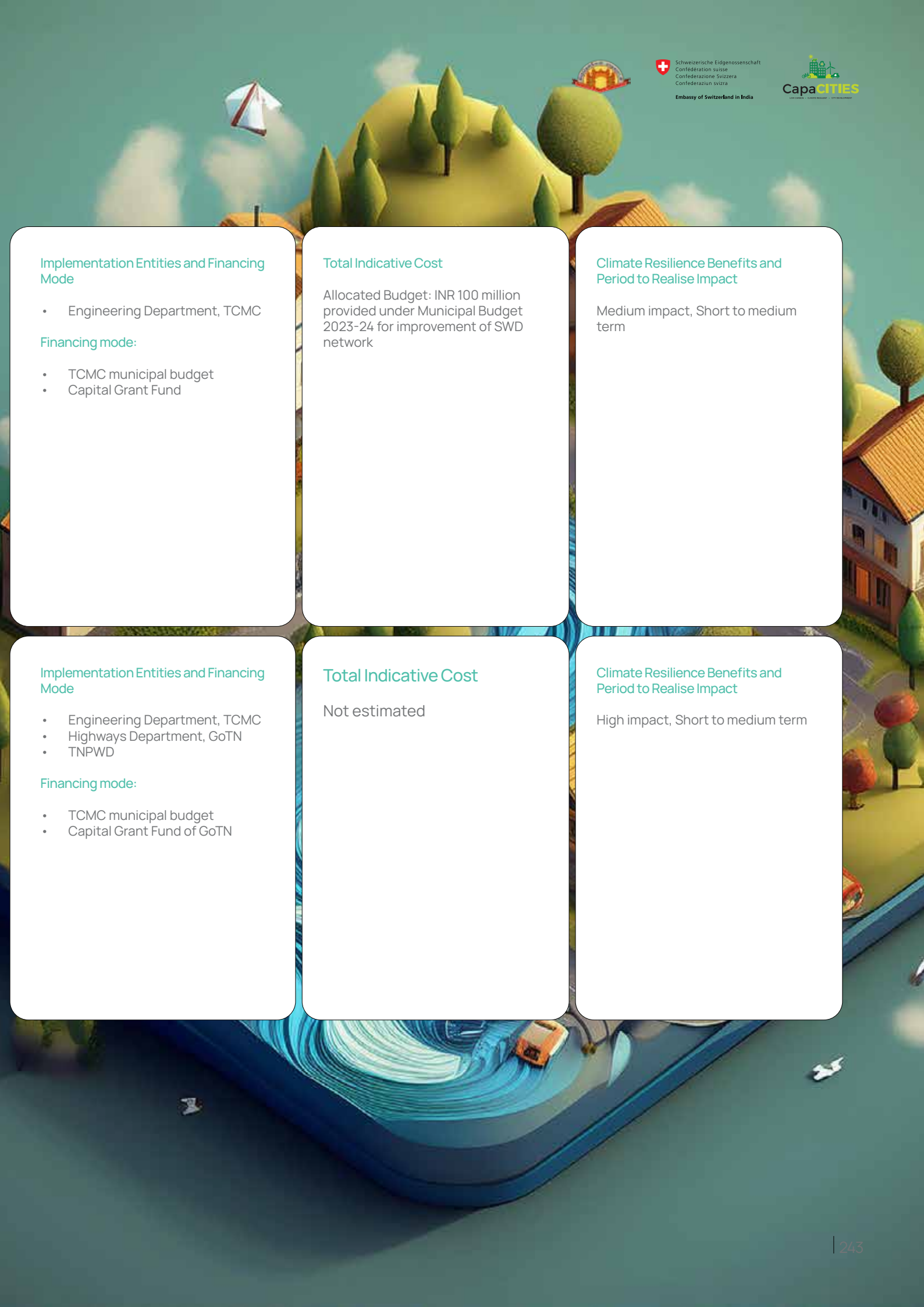
Potential locations:
Traffic junctions impacted by floods, park sites or OSR land in low-lying locations that cannot be connected to SWD network

Potential Pilot Locations:
Bio-retention pits: NH Colony, Xavier Colony, New Kakkan Nagar

Natural Swales: Drains leading to Veinthankulam in Engineers Colony, Drains leading to Periyakulam in NGO New Colony, Drains leading to Veinthankulam in RTO Road

Potential Beneficiaries:

City-wide implementation and benefits



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Implementation Entities and Financing Mode

- Engineering Department, TCMC

Financing mode:

- TCMC municipal budget
- Capital Grant Fund

Total Indicative Cost

Allocated Budget: INR 100 million provided under Municipal Budget 2023-24 for improvement of SWD network

Climate Resilience Benefits and Period to Realise Impact

Medium impact, Short to medium term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- Highways Department, GoTN
- TNPWD

Financing mode:

- TCMC municipal budget
- Capital Grant Fund of GoTN

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short to medium term

Action 3

Build green spaces and permeable pavement on footpaths.

Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:

Develop green corridors along natural drains.

Implement blue-green infrastructure such as tree box filters in pedestrian footpaths and parking zones to increase permeability of surfaces, resulting in groundwater recharge and retention of runoff.

Mandate requirement of permeable surfaces in roads and streets through 'Standard Operating Procedure for Road Construction' and including it in road tenders.

Potential Locations and Beneficiaries

Potential Locations:

All the major roads in each ward and all the roads where footpaths are available currently

Areas where canals are along the roads
Potential Beneficiaries:
City-wide implementation and benefits

Implementation Entities and Financing Mode

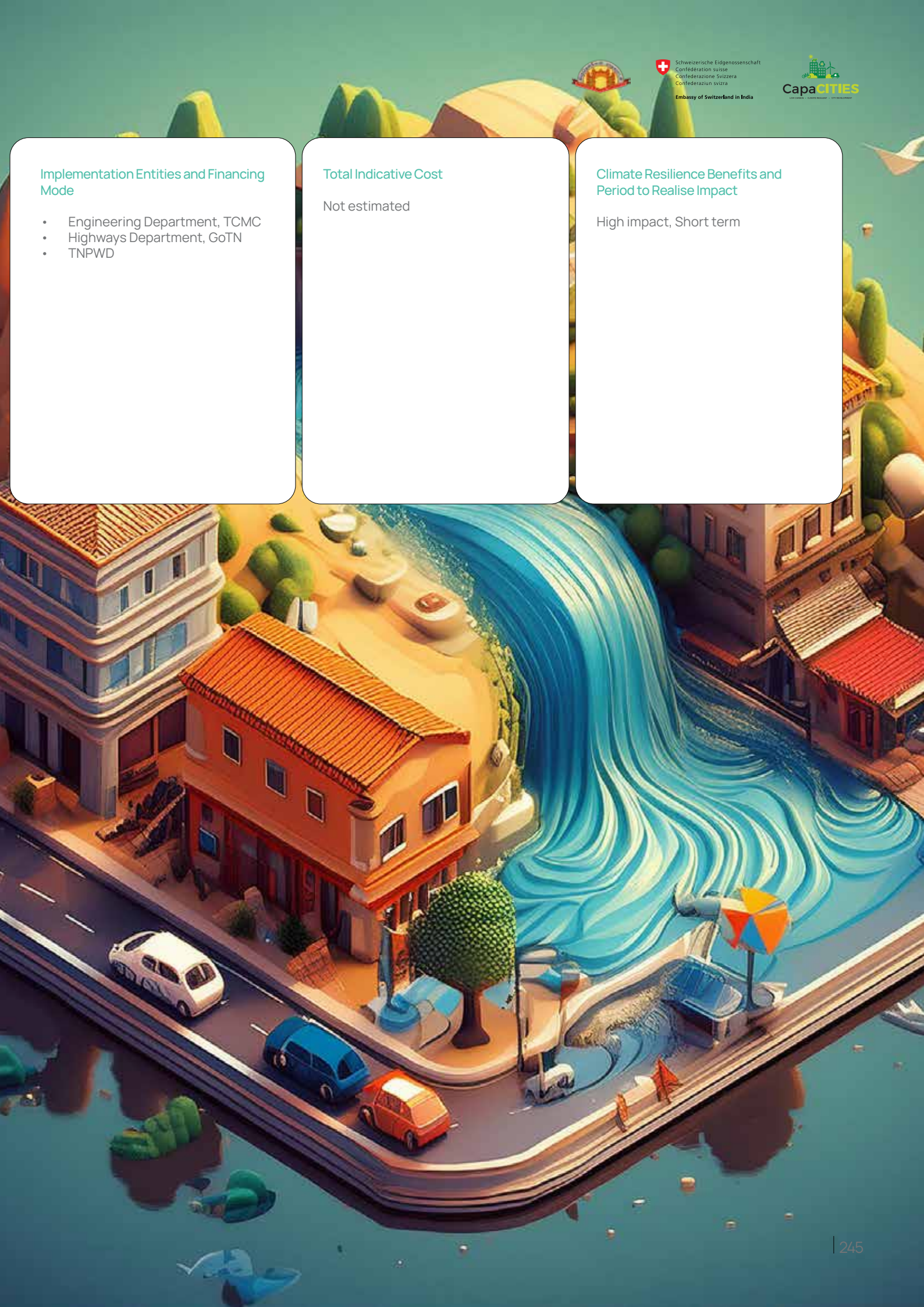
- Engineering Department, TCMC
- Highways Department, GoTN
- TNPWD

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short term



8.3.6 Solid Waste

2021

Baseline status
Solid Waste

GHG emissions:
0.02 million tCO2e (3.27% of GHG emissions)

Key statistics:
- Per capita generation: 0.415 grams/day
- Total waste generation: 230 TPD; ~95% door to door collection
- Waste processing capacity: 80 TPD
- Waste composition: Food waste (44.18%), Garden (19.59%), Paper (7.14%), Wood and straw (8.45%), Textiles (1.51%), Disposable nappies (2.08%), and Rubber (0.34%).
- Waste going to dumpsite: 80% of collected waste

Opportunities and challenges/gaps

Lack of segregation at source leads to inefficient recycling and treatment.

Awareness campaigns by TCMC for source segregation and promoting reduce, recycling and reuse to promote circular economy

Waste collection, transportation and processing is a huge challenge during festivals, especially in areas with large temples like Nellaiappar Temple in Tirunelveli old town area.

Open dumping of waste on roads blocks sewerage and stormwater drains during extreme rainfall events.

Existing policy and ongoing initiatives

GoI's Swachh Bharat Mission 2.0 supporting SWM infrastructure

Centralised pre-sorting facility and windrow composting platform to be tendered

Climate Risk and BAU GHG Emissions Scenario

Sector	BAU GHG Emissions (Million tCO2e)			Share in overall BAU GHG Emissions (%)		
	2030	2050	2070	2030	2050	2070
Solid Waste	0.04	0.06	0.1	3.23	3.91	4.59

Climate Risk Status: High I High risk during high temperature and high intensity rainfall

Blockages in the drainage network escalate during heavy rainfall periods.

Higher temperatures accelerate decomposition rates, creating hazardous conditions in open dumpsites and increasing the risk of fires.

Leachate flows from open dumpsites and garbage vulnerable points in the city, where waste is dumped often in the open, contaminate land, surface water, and groundwater.

Potential climate resilience impact from identified interventions (Net-zero scenario)

GHG Mitigation Potential and Indicative Cost of Interventions

Particulars	Net-zero Scenario Net-zero Scenario		
	2030	2050	2070
GHG emissions reduction from BAU (%)	98%	108%	113%
Total cost of mitigation actions (Million INR)	NA		
Total cost of adaptation actions (Million INR)	INR 770 million		

Climate Resilience Impact

Material recovery and revenue generation through recycling and reuse efforts leading to higher resource efficiency and circular economy

Lower fire risks in dumpsite at higher temperatures

Reduced air pollution and improved public health

SDGs

8.3.6.1 Mitigation Strategies for Solid Waste Sector

Target

Low-emission waste collection systems for **100%** waste collection

100% scientific waste processing, treatment, and disposal by 2070

Strategy 1: Achieve 100% source segregation and develop decentralised waste recovery facilities.

Action 1

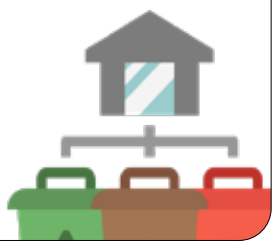
100% segregation of waste; Enhance primary and secondary collection systems.

Detailed Targets & Sub-actions

100% waste segregation and 100% collection efficiency by 2030

Action 2

Develop an updated comprehensive SWM strategy.



Detailed Targets & Sub-actions

TCMC prepared SWM strategy and action plan under CapaCITIES Phase II project, to be reviewed and updated periodically

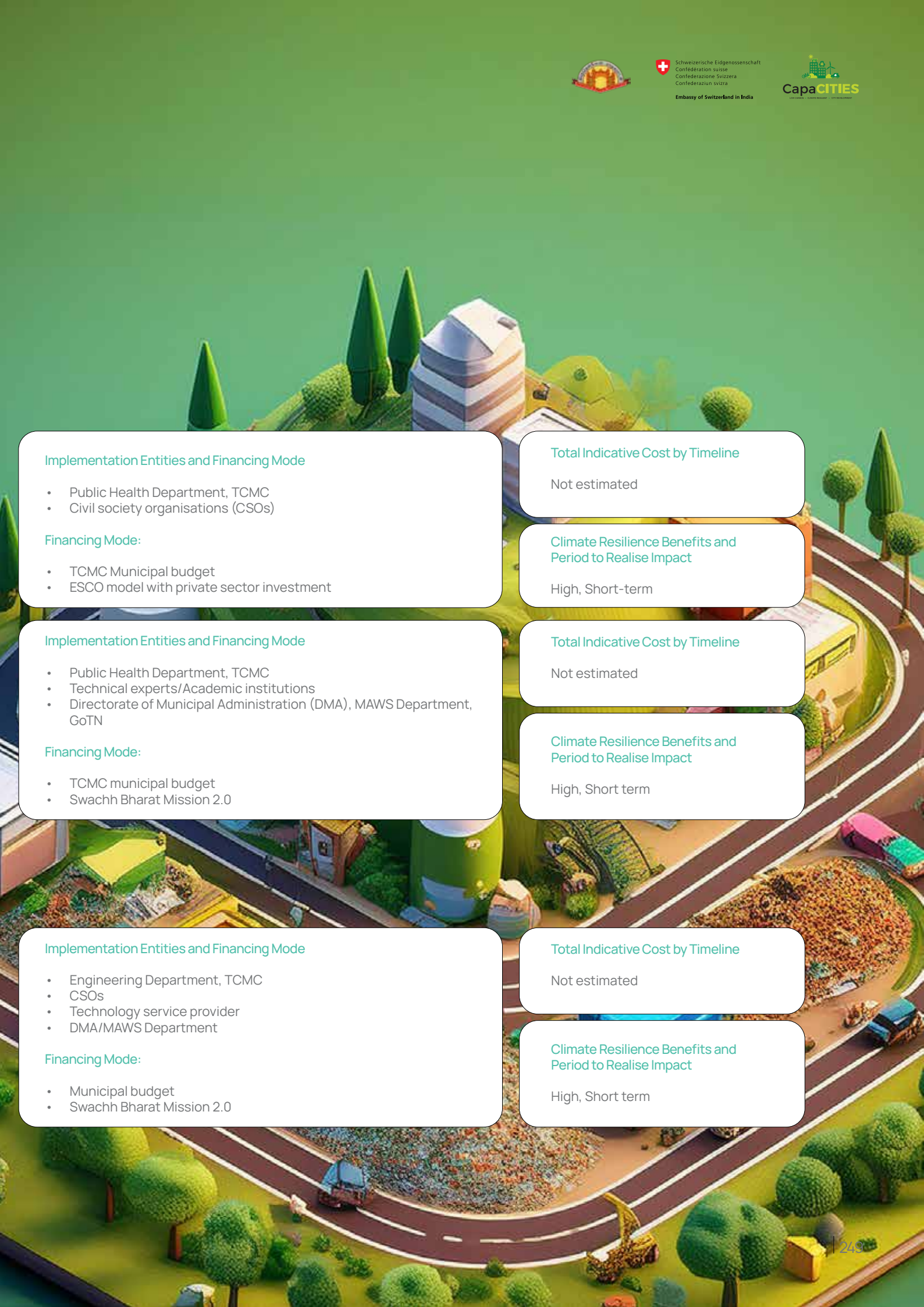
Strategy 2: Develop scientific waste processing and treatment facilities to minimise environmental hazards of waste management and disposal

Action 1

Increase composting capacity by using both centralised and decentralised facilities.

Detailed Targets & Sub-actions

100% waste processing and treatment by 2025 and beyond



Implementation Entities and Financing Mode

- Public Health Department, TCMC
- Civil society organisations (CSOs)

Financing Mode:

- TCMC Municipal budget
- ESCO model with private sector investment

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short-term

Implementation Entities and Financing Mode

- Public Health Department, TCMC
- Technical experts/Academic institutions
- Directorate of Municipal Administration (DMA), MAWS Department, GoTN

Financing Mode:

- TCMC municipal budget
- Swachh Bharat Mission 2.0

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- CSOs
- Technology service provider
- DMA/MAWS Department

Financing Mode:

- Municipal budget
- Swachh Bharat Mission 2.0

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Action 2

Deploy waste to bio-CNG plants for wet waste and produce renewable fuel from waste.

Detailed Targets & Sub-actions

100% waste processing and treatment by 2030 and beyond

Estimated capacity/size:

2030: 12% of MSW
2050: 20% of MSW
2070: 25% of MSW

Action 3

Bio-methanation

Detailed Targets & Sub-actions

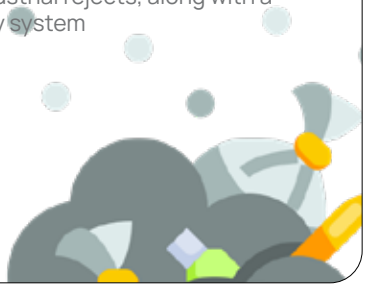
100% waste processing and treatment by 2030 and beyond

Estimated capacity/size:

2030: 8% of MSW
2050: 15% of MSW
2070: 25% of MSW

Action 4

Sanitary landfill for the scientific disposal of inert materials and industrial rejects, along with a methane recovery system



Detailed Targets & Sub-actions

Existing Scenario:

Proposed Actions:

Develop a scientifically managed dumpsite at Ramayanpatti.
Implement methane capture project to capture the landfill gas, purify and use it for vehicles and other commercial purposes.

Ensure scientific and safe disposal of solid waste at Ramayanpatti.

Enabling Actions

Address gaps in primary waste collection to improve door-to-door collection of segregated waste.

Implement effective street sweeping and cleaning initiatives citywide, including usage of street sweeping machines for major roads.

Conduct IEC campaigns and community engagement to encourage waste minimisation, proper segregation, and home composting.

Establish recognition programs, incentives, and tax rebates for households and apartments practicing effective waste management.

Enhance the implementation of Reuse, Reduce, Recycle (3R) principles through decentralised MRFs and improve the recovery of recyclable materials city-wide.

Improve secondary storage, collection, and transportation of solid waste, by developing new transfer stations with pre-sorting facilities.

Utilize GPS technology for route optimisation of waste collection vehicles to minimise fuel consumption.

Enforce regulations to reduce unscientific handling and processing of plastic, electronic, and C&D waste, and establish appropriate processing mechanisms for these waste streams.

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- CSOs
- Technology service provider
- DMA/MAWS Department

Financing Mode:

- Swachh Bharat Mission 2.0
- MNRE Waste to Energy Programme
- PPP with private sector investment and revenue from selling bio-CNG
- Support from multilateral financing institutions through TNUIFSL
- Sale of carbon credits

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- CSOs
- Technology service provider
- DMA/MAWS Department

Financing Mode:

- Swachh Bharat Mission 2.0
- MNRE Waste to Energy Programme
- PPP with private sector investment and revenue from selling bio-CNG
- Support from multilateral financing institutions through TNUIFSL
- Sale of carbon credits

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- CSOs
- Technology service provider
- DMA/MAWS Department

Financing Mode:

- TCMC municipal budget
- Swachh Bharat Mission 2.0

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short to mid-term

8.3.6.2 Adaptation Strategies for Solid Waste Sector

Goal

Transition towards circular economy by adopting measures to develop a zero-waste city.

Strategy 1: Promote circular economy practices to transition to zero-waste city by minimising solid waste generation and maximising reuse and recycling of waste.

Action 1

Promote transition towards zero-waste wards:

Sub-actions:

IEC to popularise circular economy principles and source segregation

Waste reduction strategies: Lifestyle changes and related IEC

Prevention of littering

Decentralised dry waste collection centres: Recyclables, C&D waste, and e-waste

Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: Open garbage dumping in the city clogs sewerage and stormwater drainage networks during the rainy season and increases risks of flooding.

Projects Implemented by TCMC:

IEC and awareness campaign for source segregation of waste under Nam Kuppai Namadhu Poruppu campaign of Tamil Nadu

Implementation of decentralised MCCs and OCCs

Training of MCC workers by Public Health Department officials and Anna University team

Potential Locations and Beneficiaries

- City-wide benefits

Implementation Entities and Financing Mode

- TCMC
- CSOs
- Academia
- Business bodies
- Facility managers of institutions

Action 2

Towards zero plastic waste:

Plastic value chain analysis

Ban single use plastics and promote alternatives.

Maximise recovery and recycling of plastic and other dry waste.

Incentivise private/cooperative buy-back initiatives.

Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: No dedicated plastic waste collection or door-to-door segregation taking place: One low capacity plastic waste management facility run by a self-help group is operational in the city.

Proposed Actions:

Campaigns against single use plastics

Transfer stations in Palayamkottai and Melapalayam zones with material sorting facilities

Decentralised MRFs

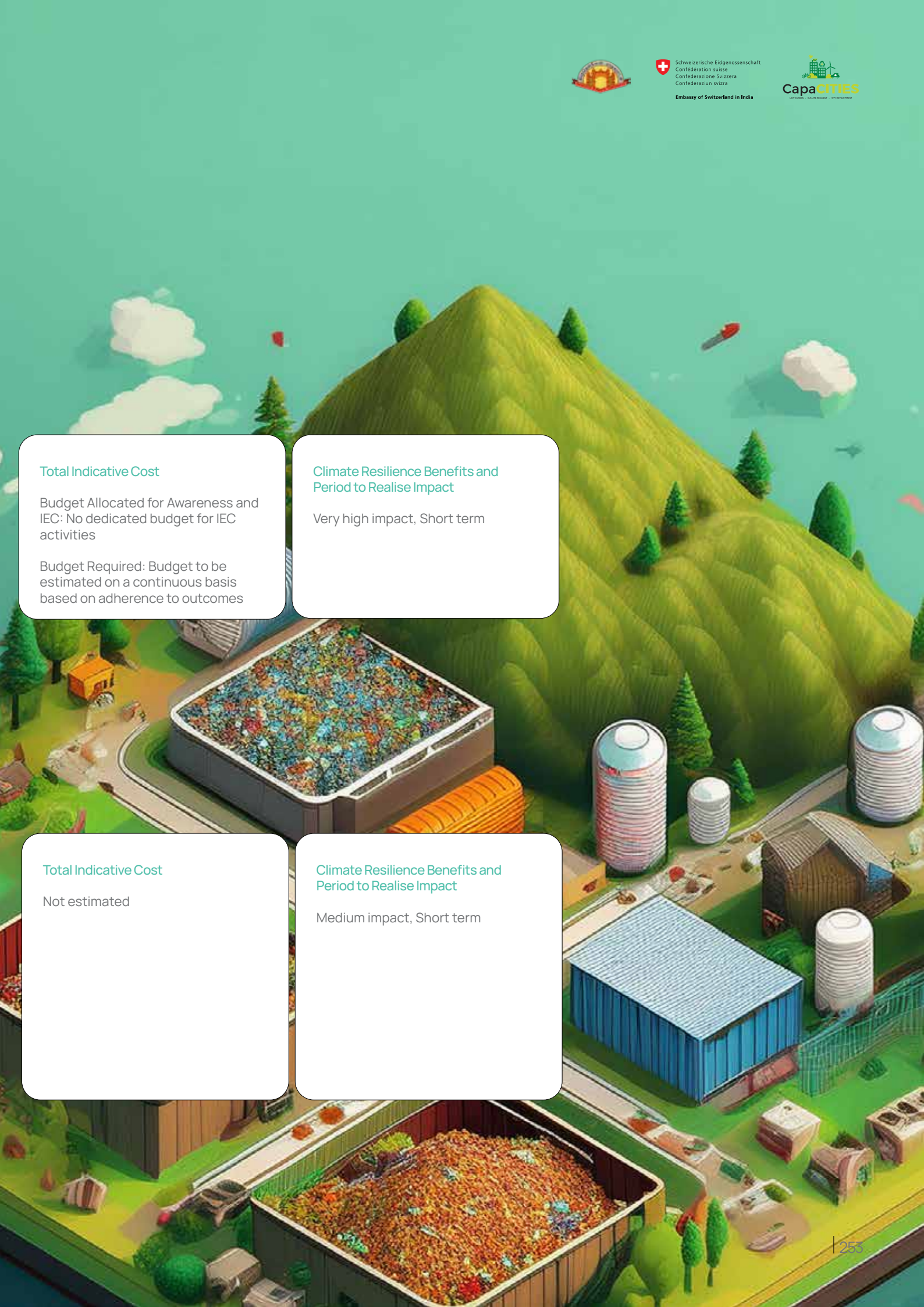
C&D and electronic waste collection centres in each zone

Potential Locations and Beneficiaries

- City-wide benefits

Implementation Entities and Financing Mode

- Public Health Department, TCMC
- TNPCB



Total Indicative Cost

Budget Allocated for Awareness and IEC: No dedicated budget for IEC activities

Budget Required: Budget to be estimated on a continuous basis based on adherence to outcomes

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Short term

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Medium impact, Short term

Action 3

Promote eco-hubs with MRFs, manufacturers of alternate material, and recyclers.

Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:

Framework to formalise rag pickers to be developed

Land allocation to develop eco-hubs with support from private players

Incentivisation and enabling framework for eco-hubs to be developed

Achieve 8%, 12%, &15% recycling rates by 2030, 2050 and 2070.

Potential Locations and Beneficiaries

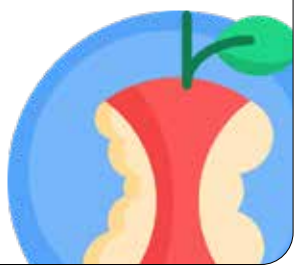
- City-wide benefits

Implementation Entities and Financing Mode

- TCMC, material manufacturers/ consumers

Action 4

Bio-mining of legacy waste and scientific management of dumpsite



Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: Bio-mining of about 0.2 million cubic metres of legacy waste completed under Smart city Mission

Proposed Action: Develop a scientifically managed dumpsite at Ramyanpatti compost yard.

Potential Locations and Beneficiaries

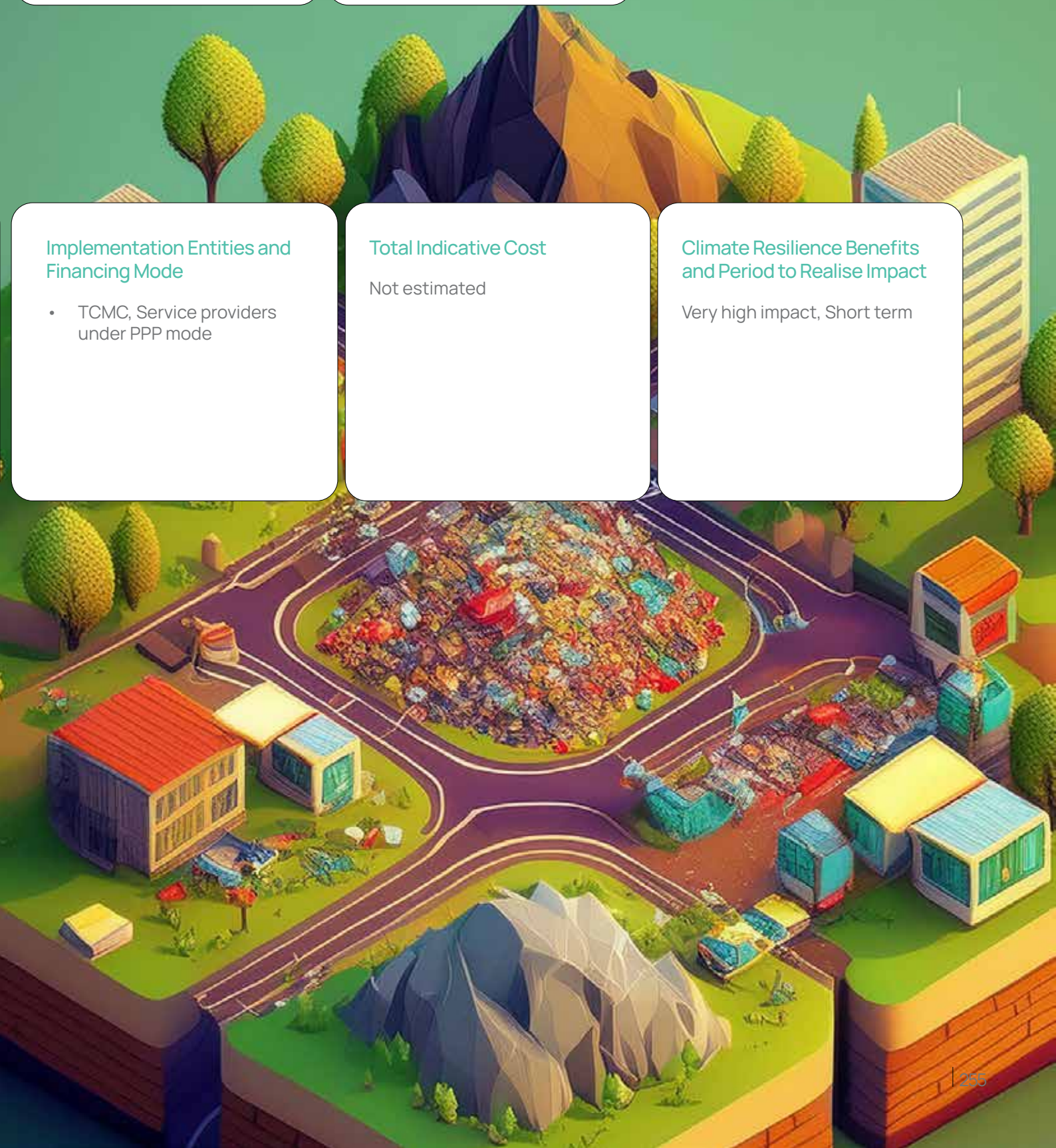
Location: Ramayanpatti dumpsite

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Medium term



Implementation Entities and Financing Mode

- TCMC, Service providers under PPP mode

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Short term

8.3.7 Urban Greening & Biodiversity

2021

Baseline status

Greening and Biodiversity

Key statistics:

- TCMC has a green cover of 27.51 sq km.
- Tirunelveli has 49.62 sq m of green cover per person which is greater than the WHO recommended minimum of 9 sq m per person.

Opportunities and challenges/gaps

As per Tirunelveli Master Plan 2021, dry agricultural land spanning 20.24% of city area is repurposed for institutional and mixed residential purposes as per the proposed land use for 2041 horizon, indicating a significant rise in impermeable surface area in the city.

Existing policy and ongoing initiatives

Under the Smart City Mission, the city developed 34 parks as green spaces at a cost of INR 365.2 million, further enhancing its urban greenery.

The city intends to develop recreational parks as green spaces in the existing vacant park sites in the city's developed areas.

Climate Risk Status: High I High risk during high temperature events and high intensity rainfall due to impermeable surface areas

Extreme heat conditions increase the heat island effect in densely populated areas.
Extreme rainfall events cause urban flooding in the city due to stormwater run-off from limited permeable areas and lack of adequate stormwater drainage network.

Potential climate resilience impact from identified interventions (Net-zero scenario)

Climate Resilience Impact

Reduces impacts of heat island effect and urban flooding, while also improving air quality and groundwater table

Improves health of the existing natural ecosystems in the city

Increase in city's carbon sequestration potential, thereby helping it achieve net-zero emissions by 2070

SDGs

3 GOOD HEALTH AND WELL-BEING
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION

8.3.7.1 Mitigation Strategies for Urban Greening & Biodiversity

Target

Improve the health of existing green cover in the city at existing levels by 2070 and increase tree canopy density.

Strategy 1: Enhance carbon sequestration through urban greening measures.

Action 1

Increase tree cover by using native tree species to leverage carbon sequestration potential.

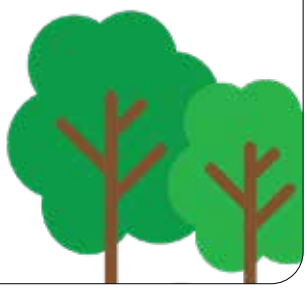
Detailed Targets & Sub-actions

Target improving green cover in wards with high heat stress using native tree species

Support and encourage CSOs already undertaking plantation drives across the city periodically.

Action 2

Increase tree cover in public parks and develop them as green spaces



Detailed Targets & Sub-actions

Proposed Actions:

Increase tree cover in more than 90 developed parks by planting additional native species of trees.

Improve irrigation techniques used in parks.

Periodic maintenance drives in parks with support from local RWAs.

Enabling Actions

Identify native tree species with high carbon sequestration potential and integrate them into greening programs and plantation drives supported by TCMC.

Explore potential of developing blue-green infrastructure, especially in undeveloped areas repurposed for development, to increase permeable surfaces and sequester atmospheric carbon.

Implementation Entities and Financing Mode

- Tirunelveli Biodiversity Committee - TCMC, Forest Department and TNPCB
- Tamil Nadu Biodiversity Board

Financing Mode:

- TCMC municipal budget
- State level schemes or missions
- CSR/CER funding
- TNGCC – TNGCF
- Nagar Van Scheme of GoI

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- Forest Department, GoTN
- Horticulture Department, GoTN

Financing Mode:

- TCMC municipal budget
- CSR funding
- Crowdfunded by local community through RWAs

Total Indicative Cost by Timeline

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High, Short term

8.3.6.2 Adaptation Strategies for Solid Waste Sector

Goal

Rejuvenate urban natural ecosystems and improve the health of existing green cover to enhance climate resilience of city.

Strategy 1: Improve the health of green cover with use of native species for plantation

Action 1

Prepare Local Biodiversity Strategies and Action Plan (LBSAP)

Sub-actions

City wide assessment to document the critical ecosystems, their present health status and the threats faced by them.

Risk assessment study of invasive alien species in major natural ecosystems of city.

Development of a strategy and action plan to improve the health of the critical ecosystems. Targeted action plans for identified species and risks.

Existing Scenario/Proposed Initiatives and Actions

Existing Scenario: No assessment of ecosystems and their health has been undertaken yet.

Potential Locations and Beneficiaries

- City-wide

Implementation Entities and Financing Mode

- Engineering and Public Health Department, TCMC
- TNPCB
- Forest Department
- Tirunelveli Biodiversity Committee - TCMC, Forest Department, and TNPCB

Action 2

Increase open green spaces and avenue tree plantation in wards exposed to heat stress.

Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:

Enhance the green cover in wards where severe heat stress is experienced.

Undertake avenue tree plantation drives with support from local community.

Increase tree cover in developed parks using native tree species.

Develop undeveloped parks as green spaces.

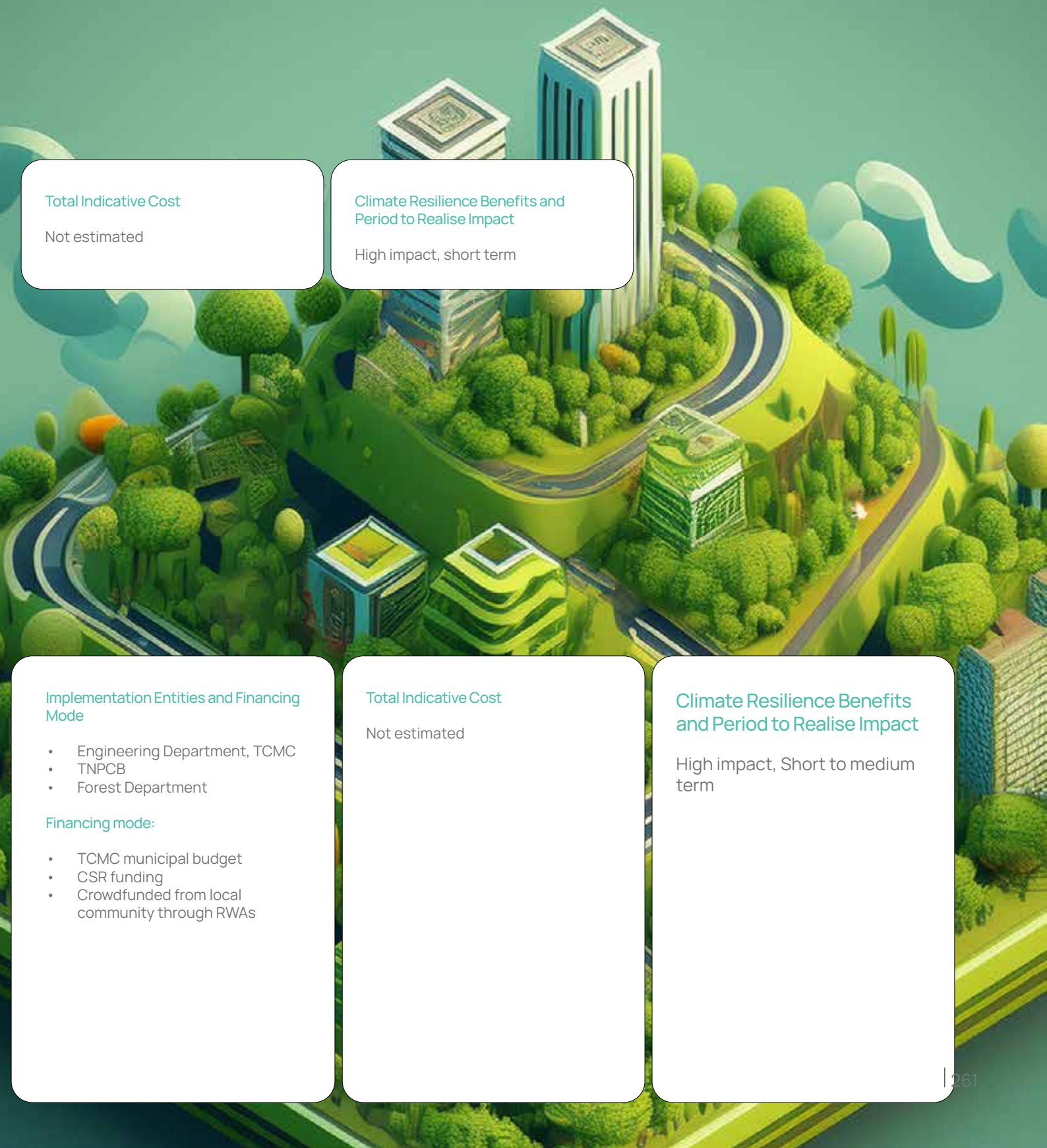
Potential Locations and Beneficiaries

Potential Locations:

- Wards 37, 38, 40, 41, 42, 52, 53, 54, and 55

Pilot Locations:

- SBI Colony park
- Thiyagarajar Nagar park near Railway Gate
- Thirumal Nagar park sites
- Teachers Colony
- Mahilchi Nagar park sites



Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, short term

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- TNPCB
- Forest Department

Financing mode:

- TCMC municipal budget
- CSR funding
- Crowdfunded from local community through RWAs

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

High impact, Short to medium term

Strategy 2: Develop blue-green infrastructure in the city and microhabitats to enrich local biodiversity.

Action 1

Develop micro-habitats in existing urban green-blue spaces such as pollinator gardens, grasslands/ scrublands, and mudflats.

Existing Scenario/Proposed Initiatives and Actions

Proposed Actions:

Develop a Natural Asset Map

Identify areas, with expert support where pollinator gardens, grasslands etc can be developed.

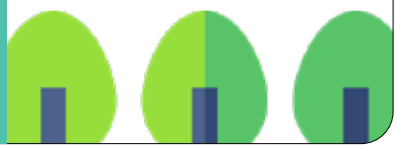
Develop the micro-habitats, with focus on native species.

Potential Locations and Beneficiaries

- City-wide initiative: Potential locations may be identified based on feasibility and expert opinion.

Action 2

Partnering with institutions to develop green corridors that link the city's blue-green ecosystems



Existing Scenario/Proposed Initiatives and Actions

Identify institutional and public areas for greening with native flora species through a city-level greening action plan.

Establish city-level nurseries in collaboration with the Forest Department.

Coordinate with partners and institutions to develop green corridors.

Potential Locations and Beneficiaries

- Pilot Locations: Green corridor along railway line in Anbu Nagar, NH colony, Maharaja Nagar and Thiyagaraja Nagar areas that are prone to urban heat risks
- City-wide initiative: Potential locations may be identified based on feasibility studies and expert opinion.

Implementation Entities and Financing Mode

- Engineering Department, TCMC
- Town planning Department, TCMC
- Forest Department, GoTN

Financing mode:

- 15th Finance Commission
- Nagar Van Scheme of MoEF&CC
- CSR/CER funding

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Medium term

Implementation Entities and Financing Mode

- TCMC, Forest Department, CSOs

Financing mode:

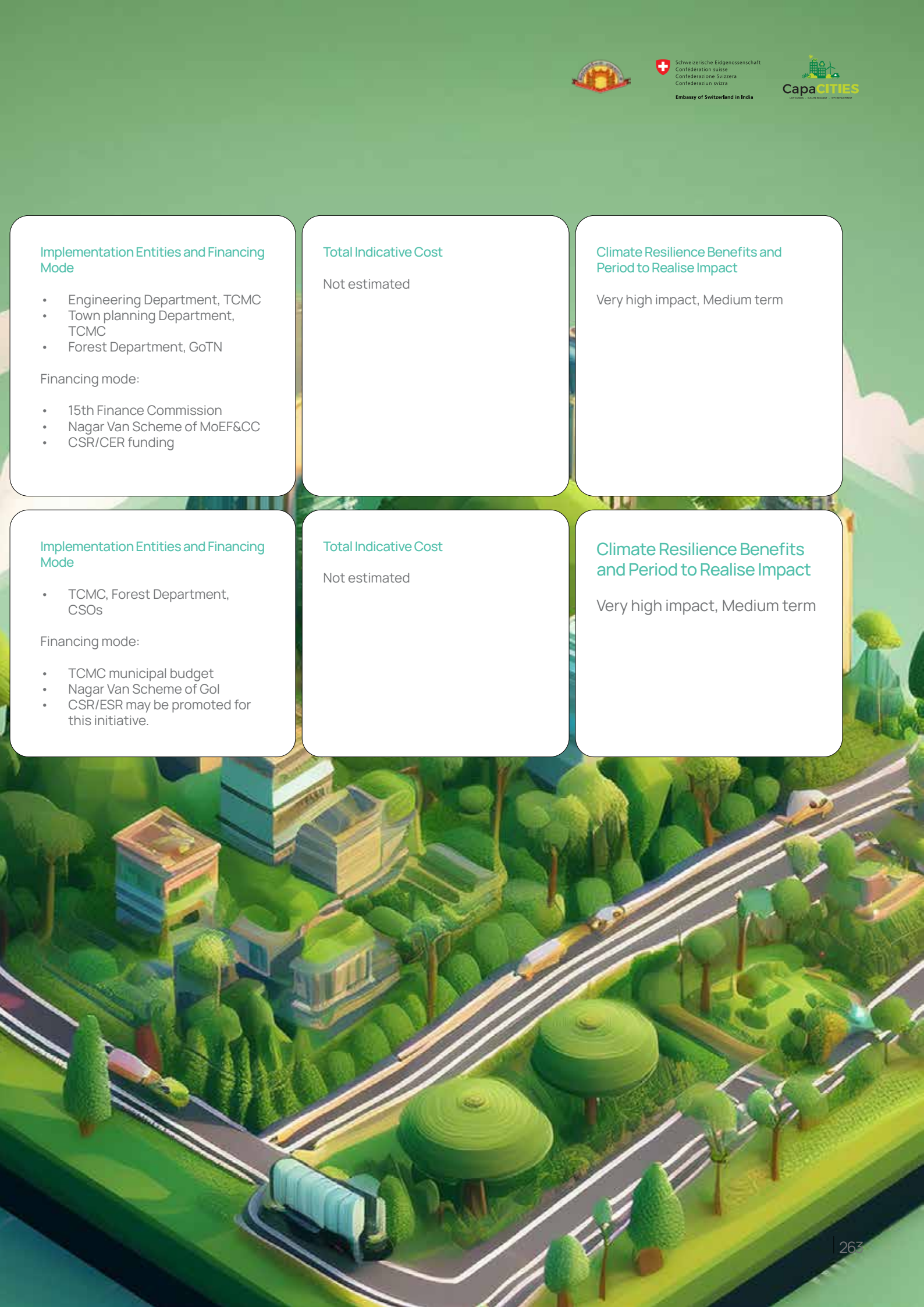
- TCMC municipal budget
- Nagar Van Scheme of GoI
- CSR/ESR may be promoted for this initiative.

Total Indicative Cost

Not estimated

Climate Resilience Benefits and Period to Realise Impact

Very high impact, Medium term



Way Forward

To achieve the ambitious climate goals and targets set for Tirunelveli under this CRCAP towards net-zero emissions by 2070, TCMC will strive to enhance awareness on climate change through community engagement, build capacity locally to support implementation of local climate actions, mobilise climate finance to implement climate actions proposed, improve its governance mechanisms and processes for data collection and management, mobilise climate finance and develop MRV frameworks to ensure effective implementation of climate actions.

9.1 Climate Awareness and Capacity Building

Effective communication and capacity building are essential to foster behavioural changes needed to achieve net-zero emissions. Through targeted initiatives, TCMC aims to enhance public understanding of climate change, promote sustainable practices, and support community-driven actions, contributing to the city's overall climate resilience and progress towards net-zero emissions. The following activities will be undertaken in this regard:

Climate Education and Awareness Programs: TCMC will collaborate with the school and higher education departments of GoTN to conduct climate change awareness and education programs. Additionally, TCMC will support grassroots initiatives such as community gardens, clean-up campaigns, and neighbourhood composting, to empower local efforts towards the net-zero goal.

Establishing Climate Information Centres: TCMC will set up Climate Information Centres (CICs) at key public locations like bus stands to disseminate climate-related information. These centres will display real-time climate and air quality data and conduct awareness activities, particularly during extreme weather events such as heavy rainfall and heatwaves, to educate the public on adaptation strategies.

Capacity Building: Recognising the urgent need for specialised knowledge and skills to address climate change challenges from an urban perspective, TCMC will undertake the following actions:

Training Programs: Conduct regular training sessions on climate science, impact assessment, and response strategies for city officials and staff. Develop a training policy and calendar for climate action.

Hiring Climate Experts: Explore hiring climate experts across various thematic areas to address capacity gaps and provide guidance on climate initiatives.

9.2 Climate Vision, Governance and Policy

To strengthen its climate governance, vision, and integrated policy making for effective climate change response and achieving the strategies outlined in Chapter 8, leading to net-zero emissions by 2070, TCMC will need to undertake the following initiatives:
Creating a Climate Vision Statement: Develop and publicly commit to a comprehensive climate vision statement that outlines TCMC's long-term goals and strategies for achieving net-zero emissions and enhancing climate resilience.

Establishing a Dedicated Climate Change Department or Cell: TCMC has established a Climate Core Team under the leadership of the Commissioner. TCMC will engage with the Directorate of Municipal Administration to expand responsibilities and allocate a budget for the Climate Core Team to evolve into a dedicated Climate Change Department or Cell to centralise all climate-related activities, including mitigation, adaptation, policy development, and coordination with other departments and external stakeholders.

Establishing a Climate Action Advisory Group: Establish a council of local experts and academicians to provide insights on evolving technologies and support the journey towards net-zero emissions.

Leveraging the Local Pool of Climate Volunteers: Tirunelveli city is blessed with several active non-profit organisations working on sustainability initiatives in the city. Leveraging the valuable contribution of volunteer community experts, TCMC will engage with them for grassroots level efforts for behavioural changes required from the citizens, and for climate resilience projects aimed at increasing the adaptation capability of the city to changing climate conditions.

Collaboration Platforms: Utilise digital collaboration platforms to facilitate communication and coordination among city departments, stakeholders, and external partners involved in climate action projects.

Integrating Climate-Responsive Urban Planning and Budgeting: TCMC will collaborate with the Directorate of Town and Country Planning to integrate climate action components into urban development plans and will integrate climate considerations into the city's budgeting process in alignment with state and national policies, ensuring that projects can contribute to net-zero objectives or climate change adaptation.

Disaggregation of State Targets: TCMC will collaborate with the state government to disaggregate TNSAPCC

targets into city-level objectives, ensuring that Tirunelveli's actions are appropriately scaled and contribute effectively to state-wide goals.

9.3 Leveraging Power of Data Analytics

During the preparation of this Net-zero CRCAP, TCMC identified the need to improve data availability and accuracy for effective analysis. Many data points and parameters were either not captured or lacked sufficient granularity. TCMC is committed to proactively addressing these data gaps in collection, management, and updates to ensure a more accurate revision of the Net-zero CRCAP and precise measurement of outcomes and progress. To bridge these gaps, TCMC will undertake the following initiatives:

Develop a Climate Data Policy: Building upon Tirunelveli Smart City's existing data policy, TCMC will develop a comprehensive data strategy with a focus on climate. The strategy will outline standards for data collection, management, and dissemination across city departments, along with guidelines for data format, reporting frequencies, and sharing protocols.

Invest in Data Infrastructure: TCMC will utilise the computing capabilities of the Integrated Command & Control Centre (ICCC), established under the Smart Cities Mission, to capture and process climate-related data. To support this effort, TCMC will invest in dedicated infrastructure, such as GIS systems for climate information, and recruit data analysts while providing training to existing staff.

Collaborate with Research Institutions: Partner with research institutions and universities to conduct joint studies and research projects. Leverage their expertise to enhance the quality and scope of climate data collection.

Capacity Building of Staff: Provide regular training for TCMC staff on data collection, management, and analysis techniques. Collaborate with academic institutions and expert organisations to deploy advanced tools, and train staff to enhance their capabilities for data collection and management.

9.4 Climate Financing

Climate financing presents a significant challenge in implementing the strategies outlined in Chapter 8. TCMC will explore various financial instruments and innovative methods to fund its climate initiatives, collaborating closely with the Directorate of Municipal Administration, GoTN, and other relevant organisations such as Tamil Nadu Infrastructure Finance Management Company (TNIFMC), Tamil Nadu Infrastructure Development Board (TNIDB), and Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL) to raise climate finance for mitigation and adaptation projects in the city. Additionally, the TCMC will undertake the following initiatives:

Establish a Dedicated Tirunelveli Climate Fund: TCMC will consider establishing a dedicated climate fund to provide a stable source of funding for climate action initiatives. This fund will be replenished by contributions from various sources, including the city budget, state and national grants, and CSR contributions from local businesses.

Leverage Public-Private Partnerships: TCMC will explore private financing opportunities for climate action projects through public-private partnerships (PPPs), by offering incentives such as tax breaks and streamlined permitting processes for businesses investing in clean energy and climate adaptation projects.

Establish Green Revolving Funds: TCMC has been implementing EE and RE projects and will explore establishing green revolving funds where cost savings from such projects are reinvested into new sustainability initiatives such as green space development, rejuvenation of lakes etc., creating a continuous funding cycle for climate action.

Crowdfunding and Community Investments: Leveraging the Namakku Naame Thittam (NNT) scheme of GoTN, TCMC will engage with citizens and businesses to finance small-scale climate initiatives and RE projects. Targeted crowdfunding campaigns and community investment programs can be explored to fund initiatives of interest to the public.

Municipal Green Taxation: TCMC will consider implementation of municipal green taxes on activities that contribute to pollution or carbon emissions and redirect the revenue towards climate action projects in the city.

Access International Climate Funds: TCMC aims to seek international climate financing for its large-scale mitigation and adaptation actions, by engaging with international climate financing mechanisms such as the Targeted Actions Programme (TAP) platform and by collaborating with development banks such as the Asian Development Bank (ADB) and World Bank to secure loans and grants.

Explore Innovative Climate Financing Instruments: TCMC may explore the following innovative climate financing instruments on the basis of appropriate feasibility assessments and other due diligence:

Carbon Credits and Trading: Develop carbon credit projects, register for carbon credits through relevant carbon registries, and participate in carbon trading markets to generate revenue by reducing emissions.

Green Municipal Bonds: Issue green bonds to finance projects that have environmental benefits, such as RE installations, EE improvements, and sustainable urban infrastructure projects.

Climate Resilience Premiums: Implement resilience premiums on property taxes for buildings that incorporate climate-resilient features and use the additional revenue to fund city-wide resilience projects.

9.5 Monitoring and Evaluating Climate Action Implementation

Institutional Framework: TCMC will establish a structured framework with the Climate Core Team overseeing the progress of implementation of this CRCAP and appoint a Nodal Officer responsible for tracking initiatives and producing annual climate action reports for Tirunelveli. TCMC will also disseminate the outcomes and learnings from its climate actions in state or national level fora.

Climate Action Reporting: The Climate Core Team of TCMC will strive to periodically analyse and audit climate actions data and make it accessible on public platforms like the Urban Outcomes Framework and Tamil Nadu Urban Liveability Framework. As committed to the Global Covenant of Mayors (GCoM) for Climate and Energy, the team will report Tirunelveli's climate actions internationally through the CDP-ICLEI Reporting Platform every year.

Integration with Smart City Infrastructure: Integrate climate action initiatives with the city's smart city infrastructure, such as the ICCC to enable central monitoring performance of various climate action projects, environmental parameters while managing city's key operations efficiently.

Leveraging Technology and Innovation: Utilise advanced technologies such as GIS, remote sensing, and data analytics to monitor and manage climate-related data, inform decision-making, and enhance the efficiency of climate action projects.

Climate Data Dashboards: Develop an interactive climate data dashboard anchored at the ICCC that aggregates and displays key environmental metrics and progress on climate action initiatives. This dashboard can be accessible to city officials and the public for transparency and accountability.

9.6 Leading in Climate Ambition and Action

TCMC is committed to achieving the ambitious net-zero emissions target well before 2070, as pledged by GoTN. Through a range of forward-thinking initiatives and robust policies, TCMC aims to showcase its dedication to climate action. This Net-zero CRCAP is designed to steer Tirunelveli towards mitigating climate change impacts, fostering local economic growth, and improving residents' lives. Aligned with state and national climate goals, Tirunelveli's CRCAP contributes to India's climate ambitions.

Building on the city's legacy of being a centre for excellence in the region with various academic institutions of repute, TCMC will leverage the technological expertise of local academic institutions to plan, implement and monitor climate actions to not only meet but exceed the targets set in this CRCAP.

TCMC believes that achieving a sustainable, climate-resilient future is a shared journey. As a non-metropolitan city with limited opportunities and modest socio-economic growth, TCMC aims to set a national and global benchmark for climate leadership by aspiring to achieve net-zero emissions ahead of schedule through bold and collaborative efforts with multiple sectors, engaging with a broad spectrum of stakeholders from government departments, private sector entities, non-governmental organisations, and the local community.

Annexures

Annexure 2.1: Tirunelveli Core Climate Team and Stakeholder Committee

Thiru.B.Vishnu Chandran, I.A.S.,
Managing Director,
Tirunelveli Smart City Limited,
Tirunelveli – 627 001
Phone : 2329328(O),
Fax : (0462) 2329327
EmailID:commr.tirunelveli@tn.gov.in

E1/1035/2021 Dated 12.5.2022

To
1.Assistant Commissioner, Tirunelvlei Ward Office
2.Assistant Commissioner, Thatchanallur Ward Office
3.Assistant Commissioner , Palayamkottai Ward Office
4.Assistant Commissioner, Melapalayam Ward Office
5. Assistant Executive Engineer, Tirunelvlei Ward Office
6.Assistant Executive Engineer, Thatchanallur Ward Office
7.Assistant Executive Engineer , Palayamkottai Ward Office
8.Assistant Executive Engineer, Melapalayam Ward Office
9.Assistant Executive Engineer, TNEB,Tirunelvlei
10.Assistant Environmental Engineer, TNPCB, Tirunelveli
11.Motor Vehicle Inspector, Regional Transport Officer, Tirunelveli
12.Assistant Manager, Tamil Nadu State Transport Corporation, Tirunelveli
13.Executive Engineer, TWAD,Tirunelveli
14.Deputy Commissioner of Police (West), Tamil Nadu Police Department, Tirunelveli
15.Assistant Engineer, (Kodagan Section), PWD, Tirunelveli
16.Forest Range Officer, District Forest Office, Tirunelveli
17.Divisional Engineer, Tamil Nadu State Highways, Tirunelveli
18.Supervisor/Dil, LPA Tirunelveli
19.Associate Professor, Department of Civil Engineering, GCE,Tirunelveli
20.Associate Professor,Department of Plant Science, Manonmaniam Sundaranar University, Tirunelveli
21.President, Nellai Nature Club Trust, Tirunelveli
22.Secretary, Nellai Nature Club Trust ,Tirunelveli

Sir,

Sub: Tirunelveli City Municipal Corporation – Formation of Stakeholder Committee for Climate Action in Tirunelveli City - Regarding

Ref: 1) MoU Signed by Tirunelveli City Municipal Corporation with Directorate of MunicipalAdministration (CMA) and CapaCITIES project Implementing Agency, dated 16/03/2021
2) Letter from Directorate of Municipal Administration on implementation of CapaCITIES Phase II project activities, dated 17/09/2021

Tirunelveli City Municipal Corporation is implementing the CapaCITIES Phase II project funded by Swiss Agency for Development and Cooperation (SDC) with support from the ICLEI South Asia team. In India, the project is being implemented in eight cities, with Coimbatore, Tiruchirappalli and Tirunelveli cities participating from Tamil Nadu. The project has signed an MoU with all 3 Project cities and with the Directorate of Municipal Administration (DMA) for providing support to the state government in mainstreaming climate considerations in the state level urban planning processes and guidelines.

CapaCITIES Phase II project aims to strengthen the capacities of the 8 Indian partner cities to identify, plan and implement measures for reducing greenhouse gas emission and for enhancing resilience to climate change in an integrated manner. City level baseline assessments, GHG Emission Inventory, Climate Vulnerability Assessment, and Climate Resilience City Action plan (CRCAP) will be

prepared as part of the project delivery. Also, pilot demonstration projects on local climate actions will be implemented and through capacity building activities, the project will enhance capacities of city officials to develop, and institutionalize climate resilience city action plans and to implement local climate actions.

A 'Climate Core Team' and a "Stakeholder Committee for Climate Action" is constituted by the Tirunelveli City Municipal Corporation under this project; and these two bodies will play a key role in successful implementation ofthe project activities in Tirunelveli City, and for facilitating climate actions well into the future beyond the scope of this project.

The Climate Core Team comprising of officials from the Tirunelveli City Municipal Corporation, coordinates the ongoing participation of the city in the CapaCITIES project, project steering and decision making. The Climate Core Team comprises of the following list of officials and is led by the Municipal Commissioner of Tirunelveli Municipal Corporation:

S.No	Name	Designation
1	B Vishnu Chandran IAS	Commissioner
2	N.S. Narayanan	City Engineer
3	Dr. Rajendran	City Health Officer
4	N.S.Narayanan	Executive Engineer (Planning)
5	A.Jahangeer Bhatcha	Assistant Commissioner (PalayamKottai Zone)
6	S. Lenin	Assistant Commissioner(Thatchanallur Zone)
7	Iyappan	Assistant Commissioner (Melapalayam Zone)
8	Byju	Assistant Executive Engineer(Tirunelveli Zone)
9	S. Lenin	Assistant Executive Engineer(Thatchanallur Zone)
10	A.Ramasamy	Assistant Executive Engineer(Melapalayam Zone)
11	T.Shanthi	Assistant Executive Engineer(Palayamkottai Zone)
12	S.Ramanathan	Assistant Executive Engineer (SWM)
12	Murugesan	Sanitary Officer(Tirunelveli Zone)
13	Elango	Sanitary Officer(Thatchanallur Zone)
14	M.Shahul Hameed	Sanitary Officer(Melapalayam Zone)
15	D.Arasa kumar	Sanitary Officer(Palayamkottai Zone)

Mr.S.Lenin,Assistant Executive Engineer, Tirunelveli Municipal Corporation, is appointedby the DMA as the **nodal officer for the CapaCITIES project**and will co-ordinate with the implementing agency for implementation of the project activities. Mr. Senthil Kumar Arumugam, Project Officer, ICLEI South Asia, will be the local coordinator for the CapaCITIES Phase II project in Tirunelveli.

The Core Climate Team will carry out participatory consultations with the stakeholder committee during preparation of the Climate Resilience City Action Plan (CRCAP). The consultation will be a two-way process of dialogue and deliberation between the Climate Core Team leading the planning process and the different stakeholders identified and included as part of the stakeholder committee. Through the consultation process the stakeholders will get an opportunity to learn about the local

government's planning process, international practices, discover potential connections to their own programs, planning and funding mechanisms, and contribute by raising issues and concerns, potentially helping to shape the strategy by making suggestions to the Climate Core Team on preparation and implementation of the Climate Resilient City Action Plan (CRCAP).

The Municipal Commissioner of Tirunelveli City Municipal Corporation will be the chairperson of the Stakeholder committee which comprises of the following list of stakeholders (based on nominations received) including from government agencies, local NGOs, community groups, and university partners:

Sl.No	Name	Designation	Organization/Body
1	B. Vishnu Chandran IAS	Municipal Commissioner	Tirunelveli City Municipal Corporation
2	S. Lenin	Assistant Executive Engineer & Project Nodal Officer	Tirunelveli City Municipal Corporation
3	M.Sankar	Assistant Executive Engineer	Tamil Nadu Electricity Board (TNEB),Tirunelveli
4	Nakkeeran	Assistant Environmental Engineer	Tamil Nadu Pollution Control Board (TNPCB),Tirunelveli
5	Rajesh	Motor Vehicle Inspector	Regional Transport Office (RTO),Tirunelveli
6	Paul Raj	Assistant Manager	Tamil Nadu State Transport Corporation (TNSTC),Tirunelveli
7	Mohamed Ali Jinnah	Executive Engineer	Tamil Nadu Water Supply and Drainage Board (TWAD),Tirunelveli
8	K Sureshkumar IPS	Deputy Commissioner of Police (West)	Tamil Nadu Police Department,Tirunelveli
9	N.Shenbaga Nandhini	Assistant Engineer(Kodagan Section)	Tamil Nadu Public Works Department (PWD),Tirunelveli
10	P.Karuppiah	Forest Range Officer	District Forest Office (DFO),Tirunelveli
11	Sathiyamoorthy	Divisional Engineer	Tamil Nadu State Highways,Tirunelveli
12	R. Raja	Supervisor/DII	Local Planning Authority,Tirunelveli
13	S.Sidhardhan	Associate Professor, Dept of Civil Engineering	Government College of Engineering (GCE), Tirunelveli
14	Dr. Selvam	Associate Professor, Dept of Plant Science	Manonmaniam Sundaranar University, Tirunelveli
15	T Amaravel Babu	President	Nellai Nature Club Trust, Tirunelveli
16	Hari Prathanam	Secretary	Nellai Nature Club Trust, Tirunelveli

Managing Director,
Tirunelveli Smart City Limited.

12/5/22

Annexure 4.1: Water Bodies in Tirunelveli city

Table A.1 Water Tanks Managed by TCMC

S. No	Name of Waterbody	Extent of the Tank in Acre
1	Kammimarkulam (Melapalayam Zone)	6.37
2	Veyilukathan Kulam (Melapalayam Zone)	52.27
3	Aanaiyarkulam (Melapalayam Zone)	6.14
4	Rajagopalapuram (Melapalayam Zone)	114.73
5	Panaiyankulam (Keelanatham Village)	35.70
6	Peerkan Kulam (VM Chatram)	19.95
7	Pillai Kulam (Kakkan Nagar)	48.71
8	Pampan Kulam (Near Gandhi Nagar, Tenkasi Road	4.91
9	Manjanathi Kulam (Sardharpuram)	4.92
10	Chettikulam (Melapalayam Zone)	1.48
11	Watcharkulam (Melapalayam Zone)	31.24
12	Periyakulam (Melapalayam Zone)	51.21

Sl.No	Tank_Name	Latitude	Longitude	Cap_ MCM
1	Thamaraikulam	8.720523628	77.66577671	0.0284
2	Mullikulam	8.724677695	77.67023488	0.0092
3	Krishnaperi kulam	8.729523966	77.67249683	0.0127
4	Kandiaperikulam	8.740594953	77.67593005	0.947
5	Thenneerkulam	8.745010595	77.69495478	0.0049
6	Ilandaikulam	8.714500012	77.73674265	0.0782
7	Seeniappanthiruthukulam	8.749356814	77.69528235	0.0125
8	Chatrampudukulam	8.760506739	77.69296492	0.6742
9	Chettikulam	8.767582684	77.70847929	0.0214

Sl.No	Tank_Name	Latitude	Longitude	Cap_ MCM
10	Karaiyiruppu kulam	8.766585956	77.72086036	0.1247
11	Murikulam	8.732660651	77.74653249	0.048
12	Nainarkulam	8.733839651	77.69166968	0.38
13	Udayarpattikulam	8.73912568	77.71365031	0.037
14	Sendimangalam	8.74987684	77.72103002	0.064
15	Pirayankulam	8.751856149	77.70957059	0.095
16	Alanganeri kulam	8.755345234	77.71400176	0.081
17	Sambankulam	8.750780912	77.70768995	0.026

Annexure 4.2: Test Results of Ramayanpatti STP Effluent

Invoice No.	Date	Amount
57	05.08.2021	Rs.13900/-

TAMIL NADU POLLUTION CONTROL BOARD

Nature of Sample: Trade effluent sample/**Sewage sample**/Water sample

1. Client Name & Address : DEE/TNPCB/TVL
2. Date and time of collection : 21.07.2021, 10.35 AM, to 11.10 AM,
3. Point of Collection :
4. Sample Received Date : 22.07.2021
5. Sample Analysis Date : 22.07.2021
6. Analysis Completion Date: 04.08.2021

1. Common inlet of STP 22
2. Outlet of anaerobic pond and inlet of facultative pond (North side) 23
3. Outlet of anaerobic pond and inlet of facultative pond (South side) 24
4. Outlet of facultative pond and inlet of maturation pond - 1 (South side)
5. Outlet of facultative pond and inlet of maturation pond - 1 (North side)

SI. No.	PARAMETER	TEST METHOD	Results						
			UNIT	LAB.C.No.	370	371	372	373	374
				DEE.C.No.	KN/07/22 D.O. Bottle No.22	KN/07/23 D.O. Bottle No.23	KN/07/24 D.O. Bottle No.24	KN/07/25 D.O. Bottle No.25	KN/07/26 D.O. Bottle No.26
1	pH @ 25° C	APHA 22nd Edt 2012, Part No. 4500 H^+	---		6.35	6.98	7.03	7.46	7.48
2	Total Suspended Solids	APHA 22nd Edt2012, Part No. 2540 D	mg/L		3620	152	140	124	116
3	BOD for 3 days @ 27° C	SI 3025:(Part 44)1993	mg/L		360	125	125	72	75
4	Fecal Coliform	APHA 22nd Edt 2012, Part No. 9221	MPN/ 100ml		38000	25000	24000	11000	13000

5.8.2021
Deputy Chief Scientific Officer,
AEL, TNPCB, Tirunelveli-10.

P.V. Jayasudha 5.8.2021
Deputy Chief Scientific Officer,
AEL, TNPCB, Tirunelveli-10.

Invoice No.	Date	Amount
57	05.08.2021	Rs.13900/-

TAMIL NADU POLLUTION CONTROL BOARD

Nature of Sample: Trade effluent sample/**Sewage sample**/Water sample

1. Client Name & Address : DEE/TNPCB/TVL
2. Date and time of collection : 21.07.2021, 11.15 AM, to 11.45 AM,
3. Point of Collection :
4. Sample Received Date : 22.07.2021
5. Sample Analysis Date : 22.07.2021
6. Analysis Completion Date: 04.08.2021

6. Outlet of facultative pond - 1 and inlet of maturation – II pond - 1 (North side)
7. Outlet of facultative pond - 1 and inlet of maturation – II pond - 1 (South side)
8. Outlet of Maturation pond – II (North side)
9. Outlet of Maturation pond – II (South side)
10. Common outlet of STP

SI. No.	PARAMETER	TEST METHOD	Results						
			UNIT	LAB.C.No.	375	376	377	378	379
				DEE.C.No.	KN/07/27 D.O. Bottle No.27	KN/07/28 D.O. Bottle No.28	KN/07/29 D.O. Bottle No.29	KN/07/30 D.O. Bottle No.30	KN/07/31 D.O. Bottle No.31
1	pH @ 25° C	APHA 22nd Edt 2012, Part No. 4500 H^+	---		7.56	7.47	7.59	7.92	7.92
2	Total Suspended Solids	APHA 22nd Edt2012, Part No. 2540 D	mg/L		72	64	38	34	36
3	BOD for 3 days @ 27° C	SI 3025:(Part 44)1993	mg/L		56	44	27	23	27
4	Fecal Coliform	APHA 22nd Edt 2012, Part No. 9221	MPN/ 100ml		9300	9200	1600	1600	1600

5.8.2021
Deputy Chief Scientific Officer,
AEL, TNPCB, Tirunelveli-10.

S.V. Jayasudha 5.8.2021
Deputy Chief Scientific Officer,
AEL, TNPCB, Tirunelveli-10.

Annexure 4.3: Chemical Characteristics of Tirunelveli Municipal Solid Waste

Table 2 Proximate, Ultimate & Macro Nutrition Analysis

S.No	Characterstics	Test Method	Units	VL-5679	VL-5680	VL-5681	VL-5682
				Mixed Waste from Landfill	Incoming waste at the Plastic Waste Management Facility	Incoming waste at the Central MCC	Incoming waste from three MCCs of pilot wards
Proximate Analysis							
1	Moisture drying at 105oC	IS 1350 Part-1	% By Weight	24.18	2.30	19.34	29.86
2	Volatile Matter (ignition at 950oC)	IS 1350 Part-1		62.16	92.07	67.92	56.57
3	Fixed Carbon	IS 1350 Part-1		3.18	1.36	2.14	2.24
4	Ash	IS 1350 Part-1		10.48	4.27	10.6	11.33
Ultimate Analysis							
5	Carbon	IS 1350-4-1	% by Weight	45.72	71.32	49.37	39.25
6	Hydrogen	IS 1350-4-1		6.32	6.62	6.39	6.23
7	Oxygen	IS 1350-4-2		35.7	16.7	31.5	40.9
8	Nitrogen	IS 1350-4-2		1.35	1.00	1.28	1.42
9	Sulphur	IS 1350 -3		0.006	0.011	0.005	0.004
10	Gross Calorific Value	IS 1350-2	KCal / kg	1685	3896	2215	1498
11	Net Calorific Value	IS 1350-2	Kcal / kg	1351	3546	1877	1168
Nutrients Levels							
12	Total Nitrogen	AST-MD-5373	% by weight	0.86	<0.1	0.48	0.92
13	Organi Carbon	ASTM D5929		31.68	53.4	28.79	32.35
14	Phosphorous as P2O5	Fertilizer(-Control) Order 1985 – July 2021		0.31	<0.1	0.29	0.32
15	Potassium as K2O			0.34	<0.1	0.31	0.34

S.No	Characterstics	Test Method	Units	VL-5679	VL-5680	VL-5681	VL-5682
				Mixed Waste from Landfill	Incoming waste at the Plastic Waste Management Facility	Incoming waste at the Central MCC	Incoming waste from three MCCs of pilot wards
Nutrients Levels							
16	Carbon Nitrogen (C:N) Ratio	–	–	36.8	< 0.1	59.97	35.16
17	Chlorides as Cl	Analar 6ed Page:472	mg / kg	6.25	< 0.1	1.86	12.47

Annexure 4.4: Sewage Outfall Points in Thamirabarani River in Tirunelveli city

Table 3 Sewage outfall points in Tirunelveli City

Thamirabarani River receives raw sewage from Tirunelveli city while passing through the city at 6 major identified locations and listed below:

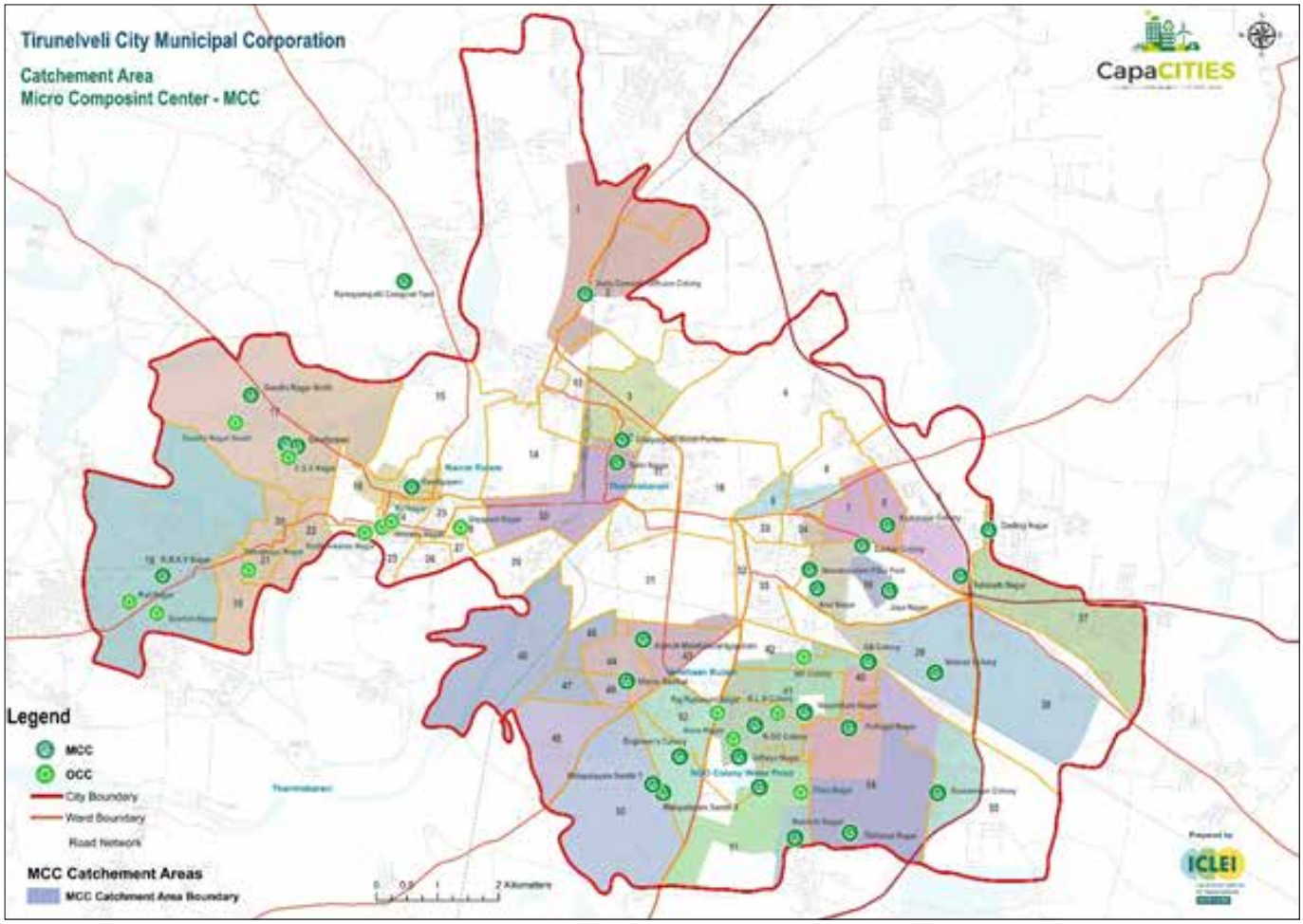
Sl. No.	Sewage outfall point	Co ordinates
1	Kurukkuthurai	08° 42' 01'' N, 77° 41' 59'' E
2	C.N Village	08° 42' 58'' N, 77° 42' 42'' E
3	Meenakshipuram	08° 43' 27'' N, 77° 42' 42'' E
4.	Kokkirakulam	08° 43' 33'' N, 77° 42' 35'' E
5	Sindupoothurai	08° 43' 36'' N, 77° 43' 8'' E
6	Manimoortheeswaram	08° 44' 16'' N, 77° 42' 57'' E

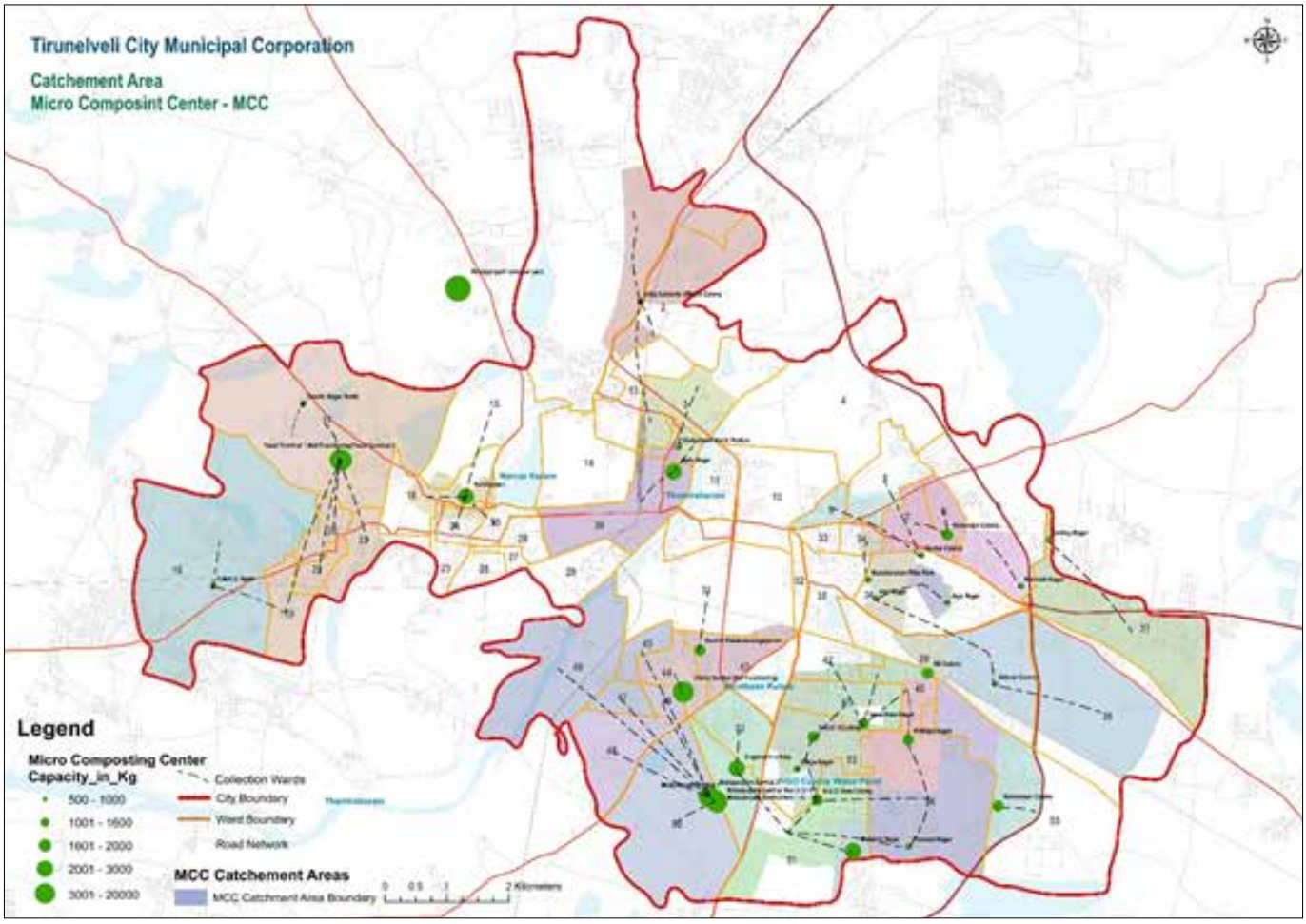
Annexure 4.6 Vehicles available for Solid Waste Management

Table 4 Vehicles available for waste collection and transportation (2022-23)

S.NO	TYPE OF VEHICLE	NO OF VEHICLES
1	LCV	7
2	Tipper	8
3	Dumper placer	4
4	Compactor	4
5	Hook Loader	3
6	JCB	1
7	HCV	4
8	Tractor	2
9	Skid Loader/ BOBCAT (Mini JCB)	8
10	Loader (Mini Hitachi)	4
11	BOV''s	216
12	Tricycles	122
13	Pushcarts	17
14	Road Sweeping Machines	1
Total		398

Annexure 4.5: Micro Compost Centres and their Catchment Areas




Tirunelveli City Municipal Corporation
Catchement Area
Micro Composint Center - MCC
Legend
Micro Composting Center
Capacity_in_Kg
500 - 1000
1001 - 1500
1501 - 2000
2001 - 3000
3001 - 20000
Collection Wards
City Boundary
Ward Boundary
Road Network
MCC Catchement Areas
MCC Catchment Area Boundary
0 0.5 1 2 Kilometers

1	WARD 01	CHITHAMBARA NAGAR COLONY	8.775816362	77.70905414
2	WARD 01	INDIA CEMENTS OFFICER'S COLONY	8.759978286	77.70851547
3	WARD 01	SELVAVIGNESH NAGAR	8.750094687	77.69924244
4	WARD 01	GOOD SHEPHARD NAGAR	8.751856912	77.70034158
5	WARD 01	NAL MAIAPPAR NAGAR	8.751835945	77.69852471
6	WARD 02	THALAVAIPURAM	8.745576851	77.70183534
7	WARD 03	BALAJI AVENUE	8.744010057	77.7085887
8	WARD 05	RAHMATH NAGAR	8.723817275	77.76270601
9	WARD 05	SHANTHI NAGAR POLICE COLONY	8.730374121	77.75653627
10	WARD 07	KAMARAJ NAGAR	8.725026762	77.75311341
11	WARD 07	SANKAR COLONY	8.722541181	77.74943499
12	WARD 08	SAKTHINAGAR	8.729334071	77.7460936
13	WARD 10	VASANTHA NAGAR, KOKKIRAKULAM	8.725960515	77.71797296
14	WARD 10	BARANI NAGAR	8.729179955	77.72538957
15	WARD 12	UDAIYARPATTI SALAI STREET	8.738391355	77.71410674
16	WARD 12	SELVI NAGAR	8.734856144	77.71333065
17	WARD 12	SOUTH BALA BACKIANAGAR	8.741469501	77.7093787
18	WARD 15	NAINARKULAM ROAD	8.737239158	77.69372484
19	WARD 16	LALUKAPURAM EAST STREET	8.731318904	77.68283059
20	WARD 17	GANDHI NAGAR B COLONY	8.745293803	77.65832941
21	WARD 17	GANDHINAGAR SOUTH	8.741379511	77.65643526
22	WARD 17	CSS Nagar	8.740783525	77.66193037
23	WARD 18	PETTAI RAIL NAGAR, CHERANMAHADEVI ROAD	8.714689267	77.64040679
24	WARD 18	SASTHRI NAGAR	8.713212024	77.64436032
25	WARD 18	VISWANATHA NAGAR (RMKV Nagar)	8.718200382	77.64546197
26	WARD 19	VEERABAGU NAGAR	8.719356748	77.65857803
27	WARD 22	KODEESHWARAN NAGAR	8.724699062	77.67570974
28	WARD 22	ABIRAMI NAGAR	8.726518463	77.67946898
29	WARD 22	R.R.J. NAGAR	8.725385433	77.67801953
30	WARD 28	VAIYAPURI NAGAR	8.725438798	77.68989343
31	WARD 29	C.N.GRAMAM WEST STREET	8.723252091	77.70103882
32	WARD 35	VOC Stadium	8.721681838	77.73250085
33	WARD 35	Sarojini Park, Kattnayakan	8.71833482	77.73385809
34	WARD 36	RAIL NAGAR	8.714689894	77.74880976
35	WARD 36	ANNA NAGAR	8.717759203	77.75040759

36	WARD 36	ARUL NAGAR	8.716174841	77.74259311
37	WARD 36	JAYA NAGAR	8.715525569	77.75314151
38	WARD 37	STAGE 3 KTC NAGAR	8.713285392	77.77678214
39	WARD 37	DEVA AVENUE	8.712435503	77.7734184
40	WARD 37	DARLING NAGAR	8.724897868	77.7680928
41	WARD 37	T.N.H.B. COLONY	8.713727937	77.76660995
42	WARD 37	KATTABOMMAN NAGAR	8.715842156	77.76917042
43	WARD 38	V.M.CHATHRAM	8.710015878	77.77060884
44	WARD 39	Kutturavu Nayanar St	8.71191705	77.74361184
45	WARD 39	M.L.Pillai Nagar	8.711619448	77.74385137
46	WARD 39	MAHARAJA NAGAR (Near Uzhavar Santhai)	8.708529873	77.74765656
47	WARD 39	MAHARAJA NAGAR (JAYENDRA PARK)	8.706604319	77.75381618
48	WARD 39	VELAVAR COLONY	8.703354378	77.76037905
49	WARD 39	MAHARAJA NAGAR (JUDU ROAD)	8.702376259	77.75679293
50	WARD 39	MAHARAJA NAGAR (VMS Backside)	8.705539362	77.7510122
51	WARD 39	PONMANI NAGAR	8.704087187	77.75860543
52	WARD 39	SARANYA NAGAR	8.708052666	77.76335988
53	WARD 39	P A Pillai Nagar	8.700362057	77.7582606
54	WARD 40	T NAGAR RAILWAY GATE PARK	8.705510538	77.74931617
55	WARD 40	VENUS GROUND	8.706215011	77.7429231
56	WARD 40	ANBU NAGAR	8.703368707	77.74224306
57	WARD 40	PONVIZHA NAGAR	8.701621915	77.74721162
58	WARD 40	PHASE-VI PONVIZH NAGAR NORTH STREET	8.702883429	77.74692355
59	WARD 41	PIONEER K S NAGAR	8.70118783	77.73095605
60	WARD 41	P&T NAGAR	8.701413574	77.73266534
61	WARD 41	RAMALINGA NAGAR	8.699907459	77.73290789
62	WARD 41	VENKATATHRI NAGAR	8.701154349	77.73512594
63	WARD 41	CHIDAMBARAM NAGAR	8.701255006	77.73585758
64	WARD 41	POTHIGAI NAGAR	8.694336022	77.7473364
65	WARD 41	Karunya Nagar	8.697171699	77.74667165
66	WARD 41	Mesia Nagar	8.697572228	77.74440261
67	WARD 41	K.L.N. COLONY	8.697106177	77.73669362
68	WARD 41	KAMARAJ ROAD, PERUMALPURAM	8.705048548	77.73985311
69	WARD 41	VASANTHA NAGAR, PERUMALPURAM	8.697269643	77.7407405
70	WARD 42	N.H. COLONY 1ST MAIN ROAD	8.705929485	77.74042247
71	WARD 43	ALAGIRIPURAM	8.706515906	77.71497266

72	WARD 48	KATTU PUTHU STREET, Nabi Nagar	8.69545217	77.70641085
73	WARD 51	NGO A COLONY	8.691476631	77.73865808
74	WARD 51	NGO A COLONY	8.688017104	77.7397677
75	WARD 51	TAMIL NAGAR (SRI RAM NAGAR)	8.677276168	77.73225426
76	WARD 51	TEACHERS COLONY	8.679707317	77.72655551
77	WARD 51	THAI NAGAR (NETHAJI ROAD)	8.695017479	77.71838329
78	WARD 51	Engineer's Colony	8.69088806	77.72210254
79	WARD 51	MAHILCHI NAGAR	8.679027148	77.73871077
80	WARD 51	CHELLATHAI NAGAR	8.681810781	77.73821164
81	WARD 51	THIRU NAGAR	8.684402471	77.73888909
82	WARD 52	HAPPY COLONY	8.699535939	77.7196557
83	WARD 53	DRIVERS OA COLONY	8.697013866	77.73589806
84	WARD 53	DRIVERS COLONY	8.697021332	77.73474748
85	WARD 53	SHARON NAGAR	8.692996474	77.73046656
86	WARD 53	ANNA NAGAR	8.693755428	77.73007118
87	WARD 53	UDAYA NAGAR	8.691860373	77.73180893
88	WARD 53	N.G.O. NEW COLONY	8.688382559	77.73515517
89	WARD 53	N.G.O. NEW COLONY 4TH STREET	8.686532023	77.73437613
90	WARD 53	N.G.O. B COLONY	8.698887116	77.73085527
91	WARD 53	RAJARAJESWARI NAGAR	8.698422877	77.72848593
92	WARD 53	NGO B COLONY (Near Amala School)	8.697071392	77.73174727
93	WARD 54	LIC COLONY	8.69399251	77.75412262
94	WARD 54	RAMACHANDRA NAGAR	8.686090206	77.74545227
95	WARD 54	THIRUMAL NAGAR NEW	8.679858277	77.74762902
96	WARD 54	THIRUMAL NAGAR 1	8.678257005	77.74760002
97	WARD 54	Valluvar Colony	8.678883746	77.74416954
98	WARD 54	THIRUMAL NAGAR 2	8.680157144	77.74308802
99	WARD 54	NEW NEHRU NAGAR	8.691411912	77.75558988
100	WARD 54	ALAGAR NAGAR, PERUMALPURAM	8.68078113	77.74559157
101	WARD 54	PERUMALPURAM EXTENSION APOLLO COL-ONY PARK	8.694614727	77.74369822
102	WARD 54	CANARA BANK COLONY	8.689265766	77.74250001
103	WARD 55	TKC NAGAR	8.699774235	77.75996796
104	WARD 55	E.B. COLONY	8.704510981	77.75014297
105	WARD 55	KUMARESAN NAGAR PARK	8.687202987	77.76088535
106	WARD 55	TVS NAGAR	8.694952598	77.7633573
107	WARD 55	Maharaja Nagar (RT Park)	8.706153421	77.74960573

Annexure 5.1: Land Surface Temperature Analysis Maps

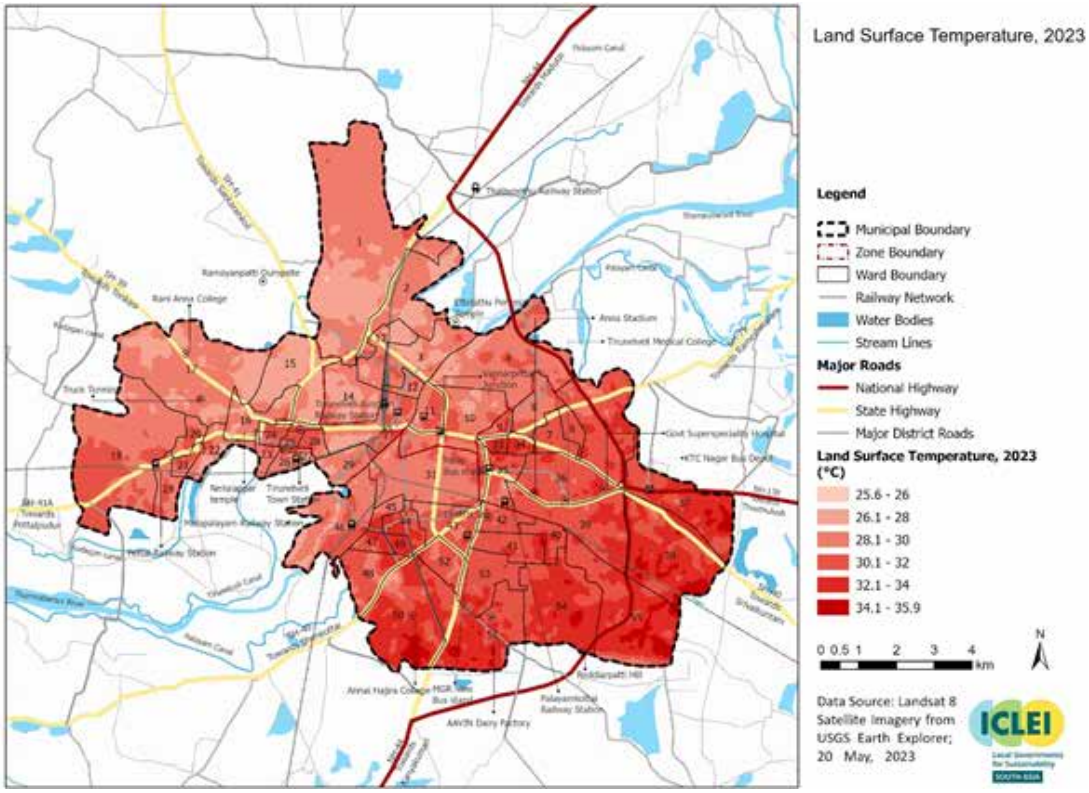


Figure 4 Daytime LST Map of May 2023

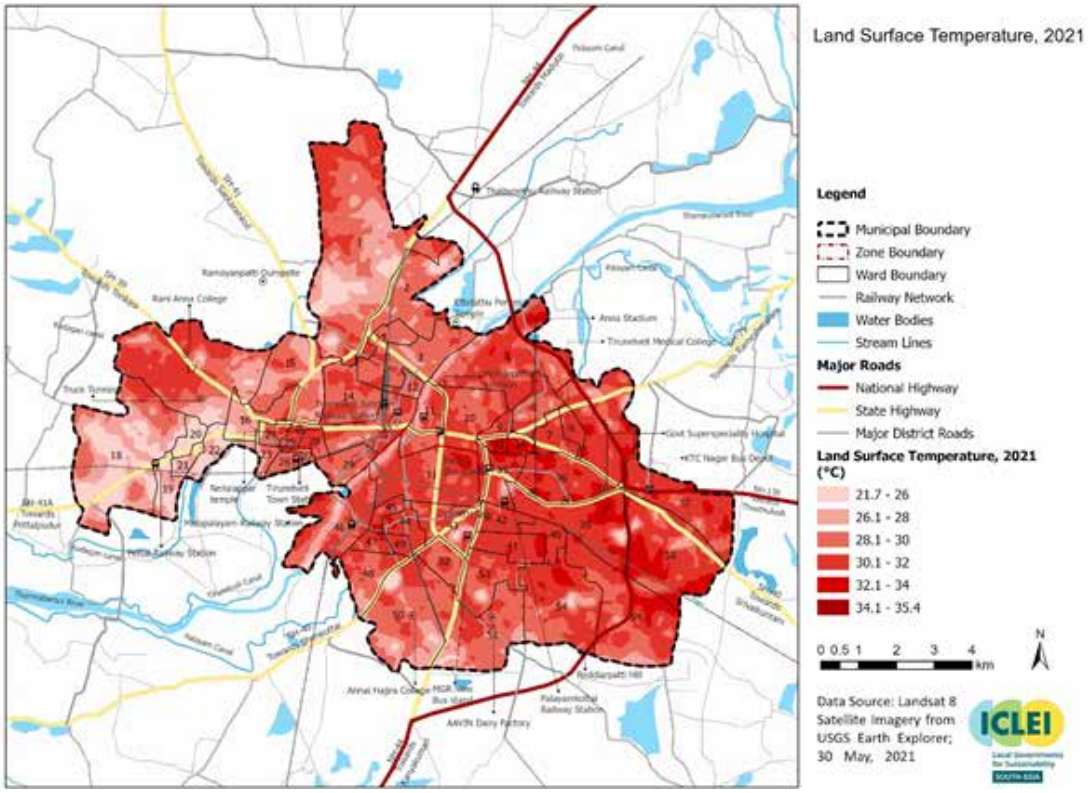


Figure 5 Daytime LST Map of May 2021

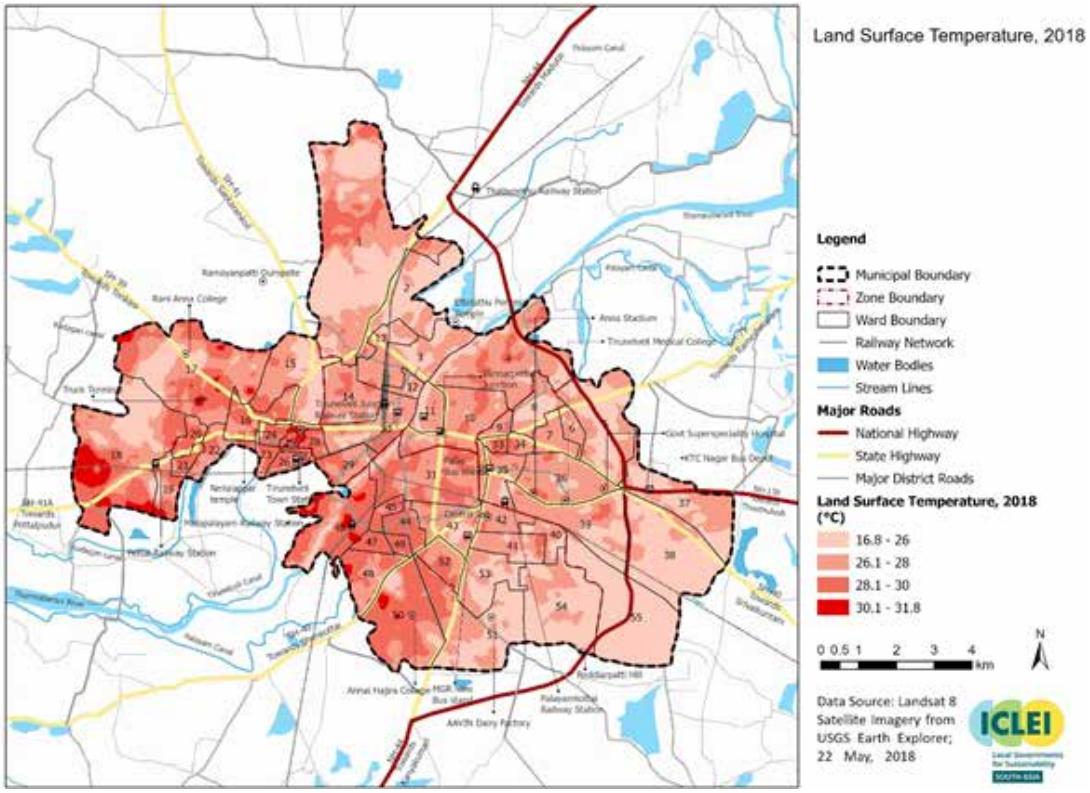


Figure 6 Daytime LST Map of May 2018

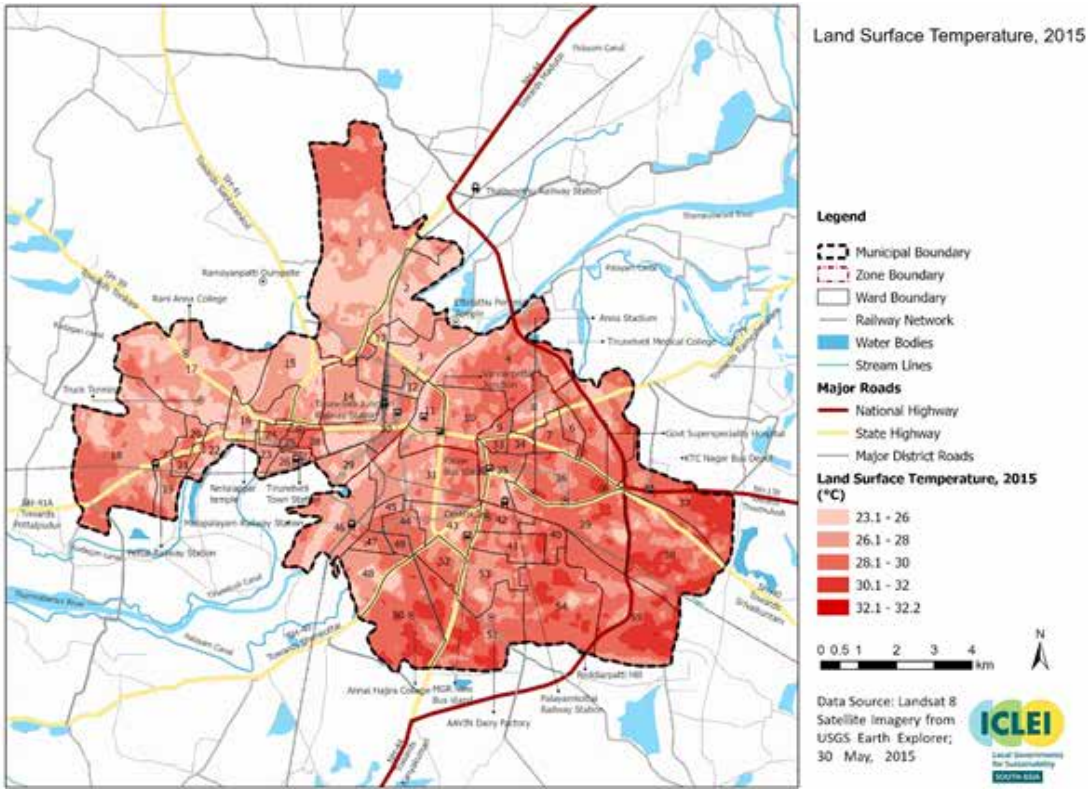


Figure 7 Daytime LST Map of May 2015

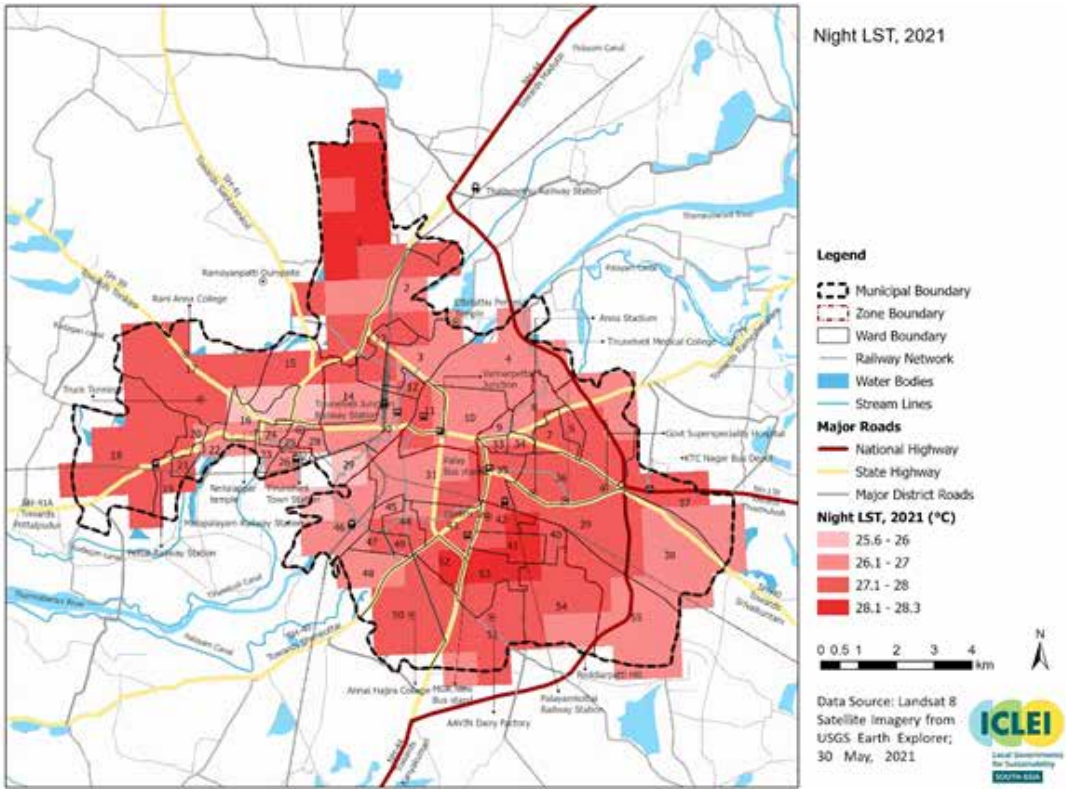


Figure 8 Nighttime LST Map of May 2021

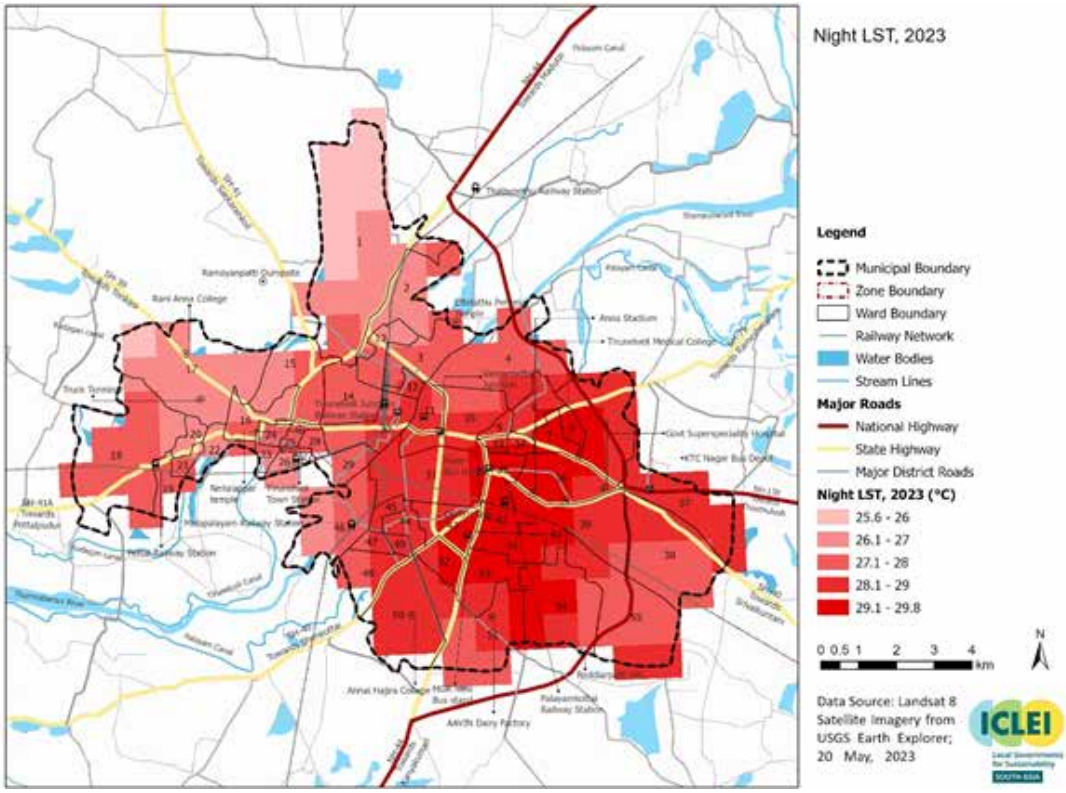


Figure 9 Nighttime LST Map of May 2023

Net-zero Climate Resilient City Action Plan 2070

Tirunelveli 2024

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